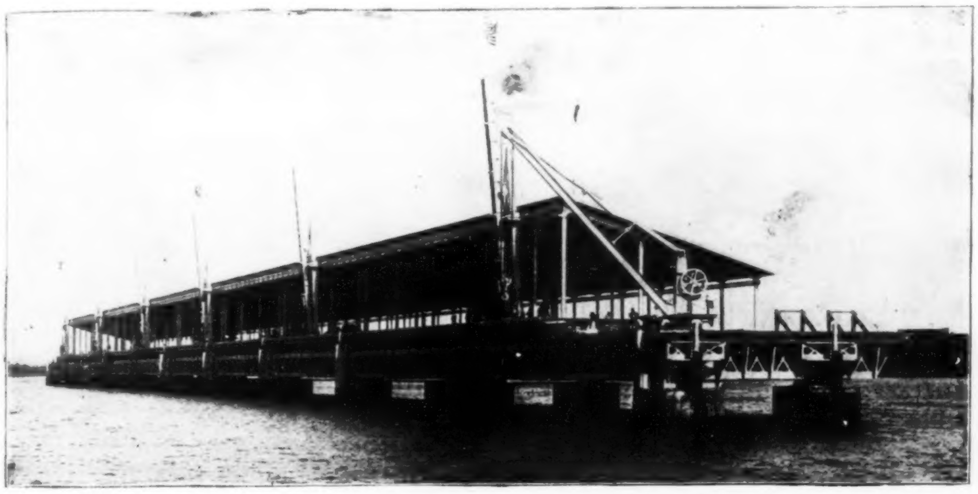
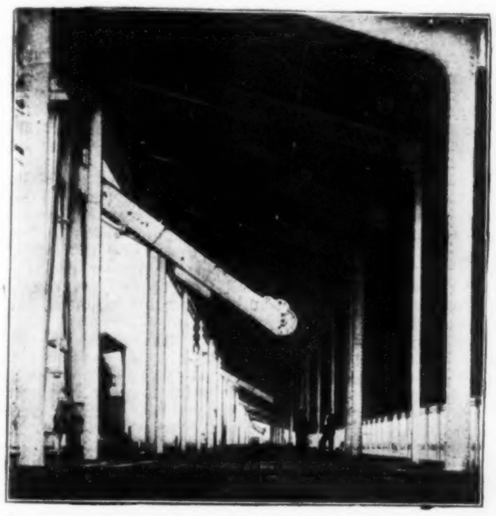
THE ISTHMIAN CANAL CONTROVERSY

SCIENTIFIC AMERICAN SUPPLEMENT. No. 1359

Vol. LIII. No. 1359. January 18, 1902.



1.—IRON PIER AND SHED AT LA BOCA, AT THE INSHORE END OF MARITIME SECTION OF PANAMA CANAL ON THE PACIFIC.



2.—VIEW LOOKING THROUGH INTERIOR OF LA BOCA PIER SHED. LENGTH, 991½ FEET.

3.—BOHIO—SITE OF LOCKS AND DAM. CHAGRES RIVER IN THE FOREGROUND. LOCKS WILL BE BUILT IN THE ROCK CUT BEYOND THE RIVER.

4.—GREAT CULEBRA CUT, 34 MILES FROM ATLANTIC. DOTTED LINE SHOWS ORIGINAL SURFACE OF MOUNTAIN.

5.—COMPLETED CANAL, 10 MILES FROM ITS ATLANTIC ENTRANCE. CANAL IS EXCAVATED TO WIDTH SHOWN FOR 15 MILES, OR UP TO BOHIO.

THE NEW PANAMA CANAL—CONDITION OF THE WORK IN 1898.

THE ISTHMIAN CANAL CONTROVERSY.

In response to a large number of requests for information regarding the present status of the Isthmian Canal question, we are devoting the present issue of the SUPPLEMENT to this important subject. Also, in the current issue of the SCIENTIFIC AMERICAN will be found a summary of the respective merits of the Nicaragua and Panama schemes, together with some maps and diagrammatic comparisons. We have endeavored to treat the matter so comprehensively that those of our readers who have not the time to read up the vast amount of literature which has appeared on the question, may still be able to obtain an intelligent grasp of the situation and judge for themselves of the relative merits of the two routes proposed.

We published in the SCIENTIFIC AMERICAN some three years ago two articles upon the Nicaragua and Panama canals. They appeared at a critical time in the history of these canals. The new Panama Canal Company plans had just received the unqualified indorsement of a technical commission composed of leading engineers from various countries, in which were included several prominent hydraulic engineers from the United States. At the same time the old Maritime Canal Company was endeavoring to commit the United States government to the financial indorsement and backing of their canal at Nicaragua; and of two expert commissions appointed by the United States government to report upon these plans, one had criticised them adversely and raised the estimated cost of construction by 100 per cent, while the second commission was known to have practically indorsed the findings of its predecessor. In the two articles above referred to, the plans of the new Panama Canal Company, of the Nicaragua Maritime Canal Company, and of the United States government commissions were fully illustrated and described. As these articles accurately describe the present conditions at both Panama and Nicaragua, we reproduce them with additional illustrations in the present issue of the SUPPLEMENT.

Shortly after the publication of these articles, the government appointed the Isthmian Canal Commission and voted one million dollars to defray the expenses of a thorough engineering investigation of the whole isthmus, for the purpose of determining the best location for a canal. The third and concluding chapter of this issue consists of a careful digest giving the essential features of this report. It must be evident to every impartial reader that while the excessive price (over $100,000,000) demanded by the new Panama Canal Company for the property caused the commission to recommend the construction of the Nicaragua route, the engineering advantages lie almost entirely with the Panama route. Moreover, as we go to press the new Panama Company is reliably reported to have made an offer of its properties for $40,000,000. This sum added to the cost of completing the Panama Canal ($144,233,358) would make the total cost $184,233,358 as against a total cost of $189,864,062 to build the Nicaragua Canal.

THE NEW PANAMA CANAL.

THERE is a broad difference between the Panama Canal as it actually is and the Panama Canal as it exists in the public mind. It would be difficult to find another great undertaking about whose present status there is so much general ignorance or positive misinformation as there is concerning the artificial waterway with which Ferdinand de Lesseps attempted to join the waters of the Atlantic and Pacific Oceans. It is a matter of history how the distinguished Frenchman, emboldened by his success in cutting the Suez Canal, undertook to open a great sea-level cutting through the mountains of the Panama Isthmus (see profile, page 21777), and failed—the physical difficulties of the project, assisted by gross corruption on the part of the promoters, serving to bankrupt the company when only a fragment of the sea-level scheme had been completed. The odium of that ill-considered and worse executed project still attaches in the public mind to the Panama Canal as such; and it is only the small minority, who have followed the subsequent course of events on the isthmus and are familiar with the heroic and successful attempts that have been made to bring order out of chaos, who are alive to the fact that the new Panama Canal project is on a sound engineering and financial footing and is within a calculable distance of completion.

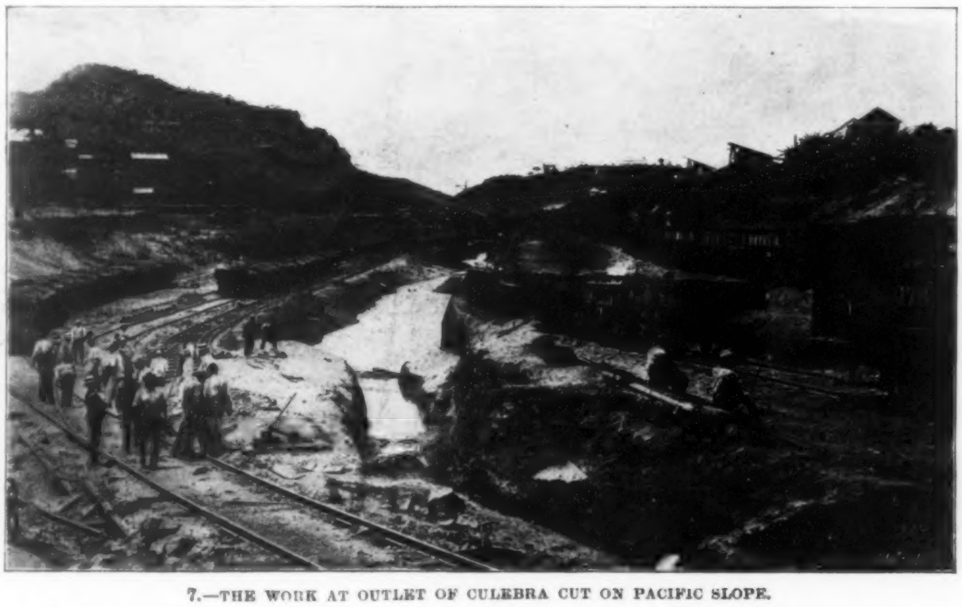
The present article is written for the purpose of putting the public in possession of the facts regarding the present status and future prospects of this undertaking. In view of the fact that one canal at the isthmus will be amply sufficient to accommodate the traffic, the question of the completion or abandonment of the Panama scheme becomes of supreme importance in considering the advisability of building a canal on the Nicaragua route, for the construction of two practically contiguous canals would mean the bankruptcy of both.

HISTORICAL.—In 1879 an international congress met in Paris, and, after investigating various routes, recommended the building of a sea-level canal from Colon, on the Atlantic, to Panama, on the Pacific. Many of the best informed members of the congress, it should be said, considered that a sea-level scheme presented too many difficulties and advocated a canal with locks; but the influence of M. de Lesseps prevailed and the sea-level route was adopted. The calculated time for completion was set at twelve years, and the cost, including interest on capital, at $240,000,000.

Now, when it is stated that the route of the proposed canal followed for over twenty-five miles a river which in the rainy season is subjected to enormous freshets, and that in passing through the Cordillera mountains an excavation 8 miles in length and varying from 100 to 325 feet in depth had to be made, it is evident that the first duty of De Lesseps was to secure the results of careful gagings of the rainfall, and to make elaborate borings along the route of the canal to ascertain the nature of the material to be excavated. Neither of these precautions was taken, or if taken, were so incompletely carried out as to leave the engineering features of the scheme very much in the air.

Work was begun in 1881. A large amount of the capital of the company was swallowed up in purchasing and placing along the line the necessary plant, in constructing shelter for 15,000 laborers, and building the necessary workshops and hospitals. The first opening up of the surface soil induced an appalling amount of sickness, and the enormous floods of the Chagres River proved altogether beyond the control of the engineers. Moreover, the upper layers of material in the great Culebra cut proved to be of a treacherous character, and the side slopes caved into the excava-

6.—FRENCH EXCAVATORS AT WORK IN THE EMPERADOR CUT.



7.—THE WORK AT OUTLET OF CULEBRA CUT ON PACIFIC SLOPE.

8.—ROCK CUT AT LA COROSITA, 28 MILES FROM THE ATLANTIC.

THE NEW PANAMA CANAL—CONDITION OF THE WORK IN 1898.

tion faster than the material could be taken out; although now that the cut has reached firmer material this difficulty has disappeared. The hopelessness of the task of building a sea-level canal was by this time apparent, and the company decided to adopt a new plan involving the construction of locks. The decision came too late. The credit of the company was not equal to the raising of further capital, and, in 1889, a receiver was appointed. At this date a sum of $156,400,000 had been expended upon the isthmus, of which about $88,600,000 had been put into excavation and embankment. The commission which examined the company's affairs states: "The enormous amount of material at hand ready to be utilized, the great number of works established, lands received, labor actually expended, experience gained, supplies laid in, preliminaries mapped out, including the right of way, are worth to the new company at least $90,000,000." The receiver obtained at this time a further extension of time from the Colombian government, carrying the date to 1904; and a later commission of six years extends the date of completion to the year 1910.

THE NEW PANAMA CANAL.—In October, 1894, a new company was formed for the purpose of completing the canal. It was organized with a cash capital of $13,000,000, and, with a view to giving it a commanding position in the financial world, the stock was purchased by several of the leading financial institutions in France, the whole $13,000,000 being actually paid in. The new company was officially recognized and its titles, etc., duly confirmed by the Colombian government.

On coming into possession, the new owners very properly determined that their first duty was to make that complete study of the engineering features of the scheme, to the lack of which the failure of the old company was largely due. They also determined to begin work on a considerable scale with a view to determining exactly what quality of material would be encountered in completing the excavations and building the various dams and locks. To this end a staff of one hundred and fifty engineers was placed in the field and a force of several thousand men was put upon the work at the more important points, including the great Culebra cut through the divide.

CULEBRA CUT.—The experience of the De Lesseps engineers and the opinion of casual visitors to the Culebra cut had agreed in indicating that the caving in of the loose material would prevent this great ditch from being successfully excavated. The new company accordingly concentrated a large force at this point and at Emperador for the purpose of ascertaining the nature of the underlying material of the mountain. A tunnel 1,100 feet in length was driven along the axis of the canal and a dozen test pits 6 feet in diameter were sunk at various points through the cut down to the proposed level of the bottom of the canal, and the shafts were connected by short tunnels. In short, the mass of material to be excavated was so thoroughly honeycombed in the regions where the worst caving had occurred as to leave no doubt as to its actual composition. Altogether, in the past four years there has been taken out of the Culebra and Emperador cuts 3,924,000 cubic yards of material, and the cost of this survey by excavation has been over $4,000,000. It was costly, but absolutely necessary to an exact estimate of the feasibility and expense of completing the canal. The evidence thus acquired proves that the "Culebra sliding mountain" does not exist, the excavation having passed through the upper layer of loose material and reached an argillaceous schist, below which, to the proposed bed of the canal, is solid rock. At Emperador the material is less firm, but perfectly capable of control when provided with proper drainage—a precaution wholly neglected in the happy-go-lucky methods of the De Lesseps regime.

THE CONTROL OF THE RIVER CHAGRES.—Another problem to be solved by the new company was that of the control of the turbulent Chagres River. By reference to the map (Fig. 9), it will be seen that the route of the canal, immediately after passing through the divide at Culebra, follows the course of the Obispo River, a tributary of the Chagres. At Obispo the canal enters the valley through which the latter river flows, and it follows this valley from mile 29 to mile 5, a distance of 24 miles. Now, during the rainy season the Chagres is liable to enormous floods, which were such as to render the canal construction on the original lines a physical impossibility.

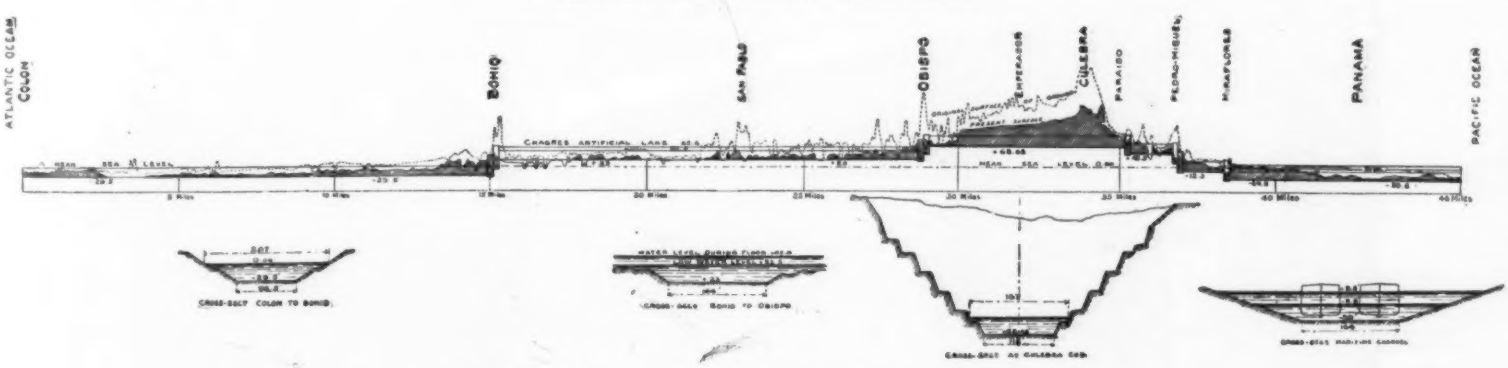
The new company decided at the outset to abandon De Lesseps' extravagant idea of a sea-level canal and substitute a system of locks. This decision opened up the question of a sufficient supply of water to compensate for losses and supply the summit level. The floods of the Chagres evidently afforded an abundant supply, and the problem then took the form of an investigation of the amount of the Chagres River discharge and the possibility of storing it in suitable reservoirs, which should at once serve to feed the summit level and to hold back the rush of the Chagres waters in times of flood. With the question of the Chagres control was associated that of the most desirable elevation of the various locks.

This investigation was intrusted to 150 engineers, who, with their corps of assistants, have been occupied for four years in exhaustive surveys, the total cost of which has amounted to $1,200,000. This includes, in addition to superintendence of the work at Culebra, extensive borings at the sites of the proposed dams and locks, sufficient to determine the exact nature of the whole site covered by their foundations; gagings of the river; the complete cross-sectioning of the basins of the proposed storage and control reservoirs, together with every kind of research that is necessary to the determination of the feasibility and cost of an engineering work of this magnitude. The investigation has been carried out to the smallest details, the drawing of every culvert, bridge, etc., being worked out with such elaboration that, on receipt of orders to go ahead with the work, these plans could be sent to the shops and the material ordered. We have had the pleasure of inspecting the engineering data, and we are free to admit that the plans, profiles, maps, shop drawings, records, etc., are as complete as the most fastidious could ask for.

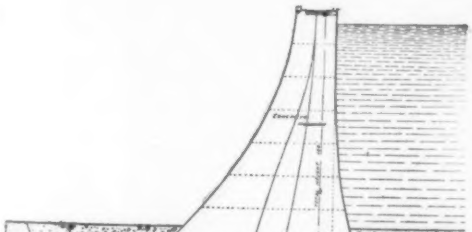
The new company has evidently laid the lesson of the first failure to heart; but, in order to give further weight to the findings of the engineers, it asked for the appointment of a Technical Commission composed of eminent engineers of different nationalities, whose experience in similar work gave them special qualifications for passing upon the new surveys and plans. The International Commission included such men as Brig.-Gen. H. L. Abbott, Corps of Engineers, U. S. A.; Mr. Fulscher, formerly Engineering Director of the Kiel Canal; Mr. Koch, engineering member of the same canal; Mr. W. Henry Hunter, Chief Engineer of the Manchester Canal Company; Mr. A. Fteley, Chief Engineer Aqueduct Commissioners, New York city; Mr. C. Skalkowski, formerly Director of Mines, Russia; and four of the former General Inspectors of Roads and Bridges, France.

This commission, organized in 1896, through some of its members has made personal inspection of the canal on the isthmus and in addition to having at its disposal the local records of rainfall and floods for the last 15

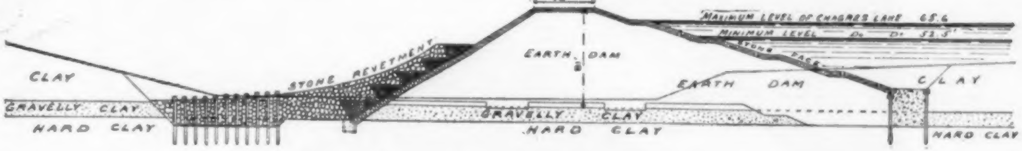
9.—GENERAL PLAN OF THE NEW PANAMA CANAL.



10.—PROFILE AND CROSS-SECTIONS OF THE NEW PANAMA CANAL.



11.—CROSS-SECTION THROUGH ALHAJUELA DAM. HEIGHT, 164 FEET. BASE, 166 FEET. LENGTH OF CREST, 936.7 FEET.



12.—CROSS-SECTION THROUGH BOHIO DAM. HEIGHT, 75½ FEET. LENGTH OF CREST, 1,286 FEET.

THE NEW PANAMA CANAL IN 1898.

years, for two years has made its own elaborate records of rainfall and of the flow and floods of the Chagres, and has held over 100 sessions. It presented a unanimous report on December 2, 1898, which, considering the standing and experience of the members, is perhaps the most representative and authoritative document of the kind ever drawn up.

The report fully indorses the plans and estimates of cost of the new canal.

THE NEW PANAMA CANAL.—The International Commission find that the work on the canal is at present two-fifths completed, that the cost to complete the work under the new plans will be $87,000,000. If 20 per cent be added for contingencies, the total cost is $102,400,000, and the time for completion, not allowing for improvements in methods of working and plant, is from eight to ten years.

The canal is forty-six miles in length. The map (Fig. 9) shows its location, and the profile (Fig. 10) shows by a dotted line the amount of excavation that has been done and by a full line and shaded portions, the excavation remaining to be done. The engineers drew up three designs for a canal with locks. In the first the summit level was to be 96¾ feet; in the second, 68.08 feet; and in the third, 32¾ feet above the sea level. The technical commission recommends the second, which is the one shown in the map and profile.

As the determination of the levels and number of locks is dependent upon the means taken to control and utilize the Chagres River, it will be well to explain that this control is secured by constructing two large dams, one at Alhajuela, in the upper Chagres, about nine and one-third miles above the canal (see map), and the other at Bohio, at the end of the sea level length of the canal on the Atlantic side. The Bohio dam will be thrown across the Chagres valley at a point about half a mile to the left of the canal at Obispo. It will be of earth, upon a bed of compact clay. The general features are shown in the cross-section, Fig. 12. The crest is 1,286 feet long, and the extreme height above the bed of the river is 75½ feet, and above the foundation 93½ feet. This dam will create a vast artificial lake, which will extend thirteen and a half miles to Obispo. Its lowest level will be 52.5 feet and its highest level, when the river is in flood, 65.5 feet. The channel of the canal will lie in the bed of this lake, which will not only take care of a large part of the flood waters, but will greatly reduce the amount of excavation necessary for the canal. The other dam, at Alhajuela, will be built everywhere upon solid rock, and will consist of concrete masonry. Its crest, 936.75 feet long, will be 134.5 feet above the river bed and 164 feet above the lowest foundation.

This dam will be connected with the summit level by a feeder with a capacity of 6,605 gallons per second. The dam will also furnish energy for the electric lighting of the canal and the electric operation of the locks, etc.

The storage capacity of the two artificial lakes thus formed will be 66 billion gallons, which provides a wide margin of safety, as shown by careful records, over any possible flood discharges of the river. The records of the flow of the upper Chagres have demonstrated that the surplus quantity of water impounded during the rainy season by the Alhajuela dam will be many times as great as will be necessary to supply the summit level during the dry season.

Commencing at Colon on the Atlantic, the first section of the canal, 15 miles in length, is tidal up to the two double locks at Bohio, by which vessels will pass into the Chagres River lake. These locks are of masonry and will be built upon rock foundations, as will all the locks of the canal. The deep cut shown in Fig. 3 is the site of the Bohio locks. The Obispo dam will be half a mile to the left of the locks in the bend of the Chagres River, which river is seen in the foreground of this same illustration. The working length of the locks will be 738.22 feet, the width of one of the twin locks being 82.02 feet and of the other 59.05 feet. Of this sea level stretch of the canal, the first 11.8 miles are navigable, the depth varying from 16.4 feet to 29.5 feet, the finished depth. It has been excavated to the original width (see Fig. 5), and not much dredging will be necessary to complete it for the whole 15 miles to Bohio. After passing the locks the canal channel extends for about 13½ miles along the bed of the lake to Obispo, where two double locks (built like all the other locks of the company upon a rock foundation) will admit vessels to the summit level 5 miles in length, where the bottom of the canal is 68.08 feet above mean sea level. On the Pacific slope admission is gained at Paraiso by one double lock to a level 7,963 feet in length, and at Pedro-Miguel two double locks lead down to a level 7,930 feet long, from which at Miraflores one double lock will admit vessels to the tide level of the Pacific. This portion of the canal is 7½ miles in length. The depth of water in the lock will be 29.5 feet and will not exceed 32.8 feet.

It should be noticed that the slopes of the canal, particularly in the Culebra cut, are to be reveted with stone, and that the curvature of the canal is easy throughout, the smallest radius being 8,200 feet and the prevailing radius 9,843 feet.

THE QUESTION OF HEALTH.—The Technical Commission examined carefully into the question of mortality and concluded that the climatic dangers have been exaggerated. It is true, during the first years of operation, owing to carelessness as to sanitation, the employment of races not used to hard labor in the tropics, and the fact that surface ground full of fever germs was being opened, the loss of life was serious. Of late years, however, owing to the employment of negroes from the British Antilles who are used to the climatic conditions, and as a result of the fact that the excavation is in the deeper rock formations, the amount of sickness is not abnormal.

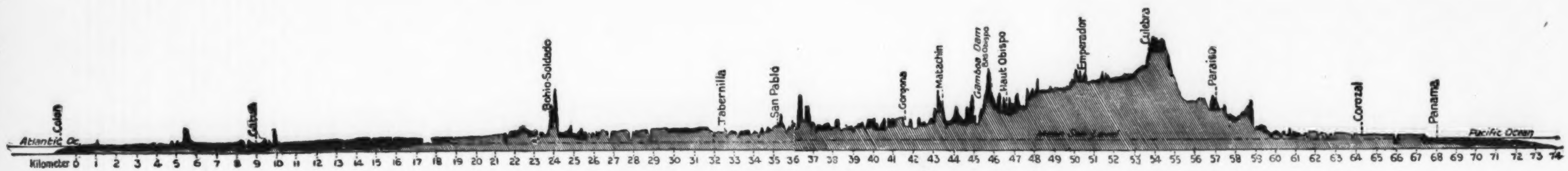
THE NICARAGUA CANAL.

THE question of an Isthmian canal is one of site, practicability, and cost. Beyond demanding that the canal as completed shall be the cheapest and best that can be built and shall secure to the United States every advantage to which it is justly entitled of a commercial, strategic and political character, we believe the public is indifferent as to whether the canal is cut through at Panama, Nicaragua or elsewhere.

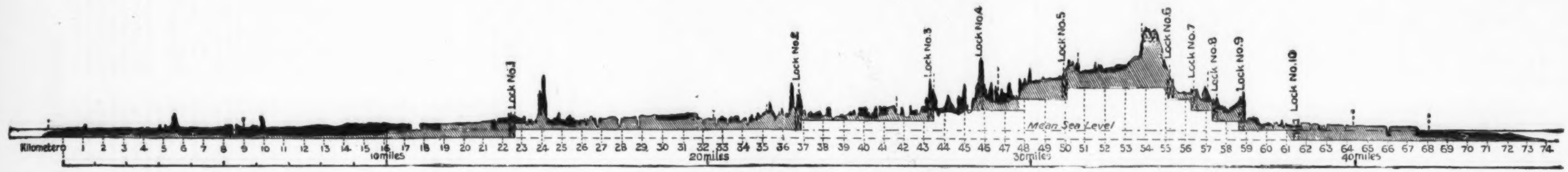
Probably there is no question involving such an enormous outlay of the public money upon which the people of the United States are so little informed as they are upon the relative standing and merits of the two proposed canals. This and the preceding article were written with a view to giving such an impartial statement of the facts as shall enable the reader to judge for himself of the relative merits and demerits of the rival schemes.

A glance at any map and profile of the proposed route of the Nicaragua Canal is sufficient to explain why it is that from the earliest times it has attracted attention as affording a feasible means of ship communication across the isthmus. The mountain range known as the Cordilleras, which forms the divide between the drainage of the Atlantic and Pacific, separates at a point about 70 miles north of Lake Nicaragua into two branches, one of which extends in a southerly direction between the lake and the Pacific, while the eastern divide runs parallel with and some 18 miles to the east of the lake and then in a southerly direction until it terminates near Greytown on the

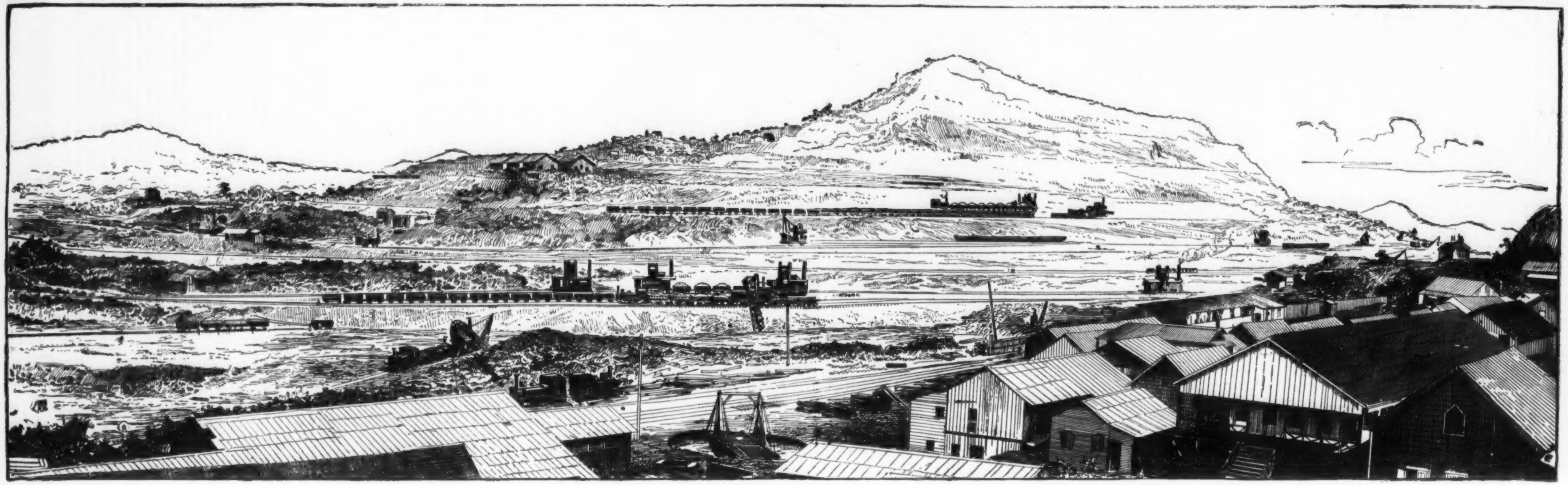
SLIDING LOCKS OF THE PANAMA CANAL—DESIGNED BY EIFFEL FOR CANAL WITH LOCKS—DATE, 1888.



THE ORIGINAL DE LESSEPS DESIGN FOR A SEA-LEVEL PANAMA CANAL—PROGRESS PROFILE, JANUARY, 1888, SHOWING IN BLACK THE COMPLETED EXCAVATION.



AMENDED DESIGN FOR A PANAMA CANAL WITH LOCKS—PROGRESS PROFILE, JANUARY, 1888, SHOWING IN WHITE THE GREAT REDUCTION IN EXCAVATION.



THE GREAT CULEBRA CUT THROUGH THE DIVIDE IN 1888.

Atlantic coast. Lying within the V formed by these ranges are Lakes Managua and Nicaragua, and into these lakes, which are connected by the river Tipitapa, there empties the drainage of this basin, which has an area of 12,000 square miles, the area of Nicaragua being somewhere between 2,700 and 3,000 square miles.

The lake is 45 miles wide by 110 miles long, and it extends in a general southeasterly direction, its longer axis being parallel with the Pacific Ocean, which at the nearest point is only 11 miles distant. The lake is for the most part deep, and its waters have a mean surface level of 106 feet above sea level. The only outlet for the waters of the lake is by the way of the San Juan, a noble stream of great volume with an average width of 1,500 feet, a minimum discharge estimated at 12,000 cubic feet per second, and a flood discharge which has been estimated by some authorities as 60,000 and by others as high as 150,000 cubic feet per second, the latter amount being two-thirds the average flow of Niagara itself. The river flows for 120 miles to the Atlantic and is navigable for river steamers, except at some rapids, which in the dry season offer obstruction. On the north side but a few streams flow into the San Juan, but the streams that enter it from the south are large and subject to heavy floods which carry down immense volumes of sand from the Costa Rican range some 50 miles distant. The most turbulent tributary is the San Carlos, which flows into the San Juan above Ochoa. The sand and volcanic ash thus brought down are carried by the San Juan and Colorado to the coast, where an extensive delta has accumulated and is steadily encroaching upon the sea.

The navigability of the San Juan and the lake, and the narrow divide separating the lake from the Pacific, have, from very early times, suggested the possibility of opening a ship canal across the isthmus at this point, and surveys of a general and preliminary character looking to this object were made as long ago as the close of the eighteenth century.

coast to the lake was to be by way of the Rio Grande Valley, and by means of 11 locks of 10½ feet lift, and the canal was to be cut directly through the western divide to the lake. This portion was to be 16¼ miles long. The route across the lake was to be 56½ miles long. The San Juan was to be navigated by placing dams in the river at four places, the uppermost at Castillo, the lowest a mile below the mouth of the San Carlos. This river portion was to be 66½ miles long. At the lowest dam the canal was to leave the river, follow its left bank to the San Juanillo, and then proceed by a straight course to Greytown. The total length of the canal from ocean to ocean was to be 181¼ miles. As Greytown Harbor had been silted up since the Childs survey, an estimate of $2,500,000 was made for its restoration. The total cost of the project, including 25 per cent for contingencies, was estimated at $65,722,147.

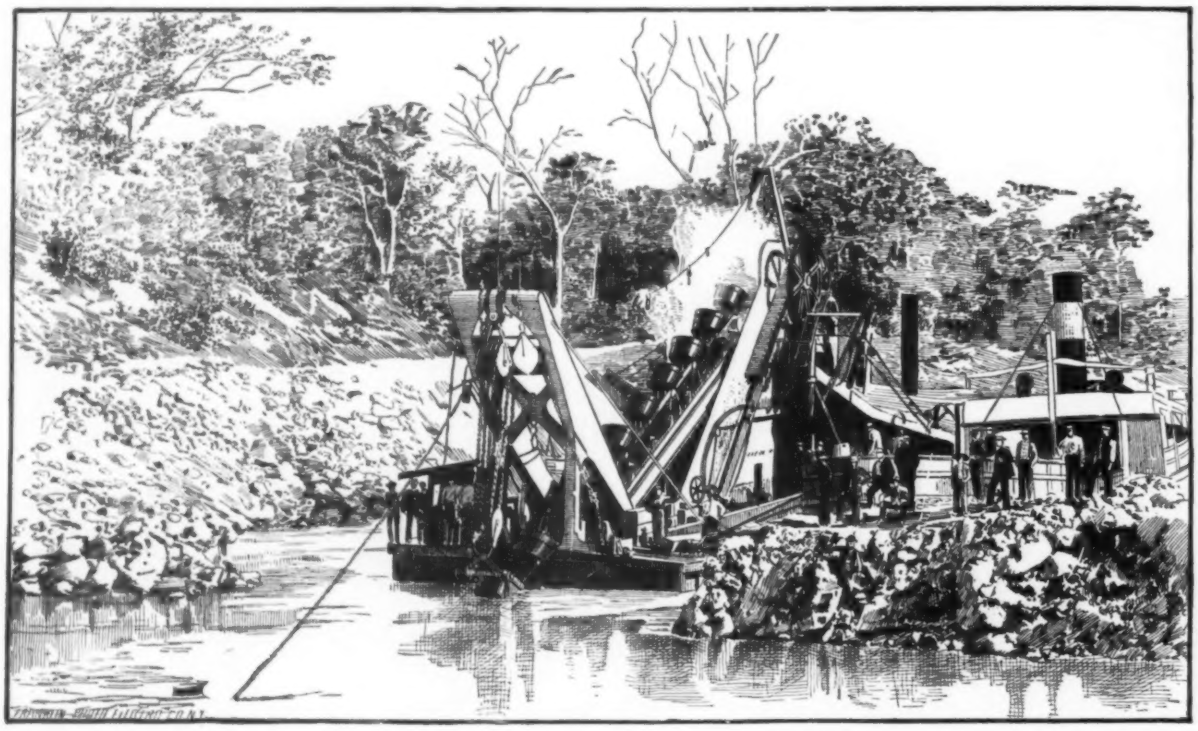
THE MARITIME CANAL COMPANY'S SURVEY, 1887 to 1890.—The next step was taken in 1885, when Mr. Menocal was directed by the government to make a reexamination of the work, and estimate for the construction of a 28-foot canal. In his report of that year he recommended some very radical changes in the Lull plan and outlined a project which involved some bold engineering measures, especially in the canalization of the San Juan River. The total estimate for the canal was $60,036,197. Four years later Mr. Menocal returned to the isthmus as chief engineer of a company (the Maritime Canal Company), which had been formed for the purpose of building the canal on the general lines proposed by him in the 1885 report. A large engineering force was put in the field between the years 1887 and 1890, and in the latter year a report was presented by Mr. Menocal and elaborated in the Chicago Waterways Congress of 1893, setting forth the data and plans upon which it was proposed to build the canal.

It is admitted by the many expert engineers who have criticised the Menocal project that if it were pos-

lakes, known as the San Francisco and Deseado basins connected by short lengths of canal. Lock 3 is only 13 miles from the Atlantic (Caribbean Sea), so that by this original and daring proposal the summit level would be extended continuously for 154 miles across the isthmus, its eastern terminus being within 13 miles and its western terminus within two miles of the respective oceans. On both sides descent was to be made to sea level by three locks. At the Pacific level the lowest lock would be within a mile of the deep water and on the Atlantic it would be necessary to dredge a canal 9.4 miles in length through the alluvial deposits of the river.

CONSTRUCTION OF DAMS.—Now, to construct a dam 60 to 80 feet high across a great river whose waters in time of flood may be over one-half as great in volume as the flow of Niagara is a stupendous undertaking. Mr. Menocal evidently realized that it was hopeless to divert the river, lay bare its bed, expose the underlying rock, and build up an impervious dam in the ordinary way, for he proposed to make a high, loose-rock fill across the river, dumping in the material excavated from the big cut through the eastern divide in as large blocks as possible. The rock, of which the cut would afford an abundant supply, was to be dumped in until it had ceased to sink into the soft bed of the river and a stable structure had been secured. To render it impervious, the excavated clay from the neighborhood was to be dumped upon the upstream face of the dam. A similar method of construction was to be used for the numerous embankments of the San Francisco and other streams crossed by the canal, and for La Flor dam. The most startling proposal of all, however, was that to use the rock-fill dams as weirs over which the surplus waters of the lake and rivers were to discharge.

HARBORS.—All the surveys that have been made for a canal have realized the necessity of creating terminal harbors at each seaboard. On the Pacific the canal terminates at Brito, an indentation of the coast,



EXCAVATING PLANT AT PANAMA—FRENCH DREDGE.

THE CHILDS SURVEY, 1852.—The first actual survey for a canal was that made in 1850-52 by Col. O. M. Childs, an expert canal and railway engineer of great distinction, for the Transit Company, which had a steamer and stage line across the isthmus as part of a route from New York to California. Steamers ran up the San Juan from Greytown and crossed the lake to its west coast, where they connected with a stage line to the Pacific. The survey was for a waterway with a depth throughout of 17 feet. In the canal portion the bottom width was to be 50 feet, while in the excavated channels in the river and lake the bottom width was to be 150 feet. Locks were to be 250 by 60 by 17 feet. Ships were to pass from the sea level on each side of the summit lake level of 108 feet by 14 locks, each with an 8-foot lift. The lake was to be held at 108 feet elevation by a dam in the Rio Grande Valley 9¾ miles west of the lake and another at Castillo Rapids 37¼ miles east of the lake in the San Juan River. The lowest lock on the east side was to be at a point 90 miles from the lake, where the canal was to leave the river and extend across the flat alluvial land to Greytown, where at that time there was a well-protected harbor. The total length of the Childs canal was to have been 194.4 miles, and its cost, including 15 per cent for contingencies, was estimated at $31,538,319.

THE LULL SURVEY, 1873.—The United States government sent an expedition to the isthmus in 1872 under Commander Lull, U. S. N., for the purpose of making a resurvey of the Childs route. With Commander Lull was associated Mr. A. G. Menocal, the present engineer of the Maritime Canal Company. The depth of the canal was to be 26 feet and its bottom width 50, 60, and 72 feet, according to locality. In the excavated river channel the bottom width was to be 80 feet and something over 80 feet in the lake channel.

Commander Lull proposed several changes. The Pacific terminus was to be the same as that proposed by Childs, namely, Brito. The ascent from the Pacific

sible to eliminate from it certain elements of danger, it would provide a canal which would be in every way superior to the other alternative plans which have been submitted. Its most striking feature was that it proposed to extend the summit level of 110 feet almost from ocean to ocean. This was to be done by the construction of two great dams, one at La Flor on the Pacific slope of the western divide, at a narrow gorge in the Rio Grande Valley, 3.8 miles from the Pacific, and the other at Ochoa, a point on the San Juan, 3½ miles below the San Carlos River and 64½ miles from the lake. The Ochoa dam would rise 60 feet above the water surface of the San Juan at that point and would cause its waters and those of the San Carlos to back up and flood the two valleys, converting them into lakes which would actually form extensions of the Nicaragua Lake itself. An important feature of the design was the use of the San Carlos Lake as a settling basin for detritus brought down from the mountains. La Flor dam on the Pacific, being placed below the mouth of the Tola, a tributary of the Rio Grande, would similarly flood the Tola Valley, converting it into another lake at the level of and forming part of the big lake.

Nor was this all. With a view to shortening the route and still further extending the summit level, Mr. Menocal proposed to proceed to Greytown, not, as Lull and Childs advised, by way of the marshy lowlands through which the San Juan finds its way to the sea, but by a direct route across the intervening ridges and valleys, and through the crest of the eastern divide. To do this he proposed to raise embankments across the lower side of the valleys and make cuttings through the intervening ridges, and allow the San Juan waters to flood the basins thus formed, the embankments being built to the same height as the Ochoa dam and serving to maintain the summit level right through the eastern divide and up to lock number 3 (see profile). The portion between the Ochoa dam and lock 3 would thus consist of two large artificial

while at the Atlantic it ends on the shifting sands which have silted up what was once the deep-water harbor of Greytown. At Brito both Childs and Lull estimated that a new harbor would cost about two and one-half million dollars, while the Maritime Company's estimate put it at about one and three-quarters million dollars. It was proposed to create the harbor by running out projecting jetties and dredging out an interior basin. The construction presents no problems that are novel or untried in engineering practice. At Greytown, however, as a study of the accompanying map will show, the problem will require careful study, and after the harbor is complete will call for continual dredging and successive additions to the jetty. To understand the conditions we must bear in mind two things: First, that for ten months of the year the trade winds and seas move upon the beach from the northeast; second, that enormous masses of volcanic silt are brought down by the San Juan and deposited, through the Colorado branch, at its mouth, to the eastward of the harbor. The waves, striking this material at an angle with the coast, transport it to the westward to the amount, as estimated by the present Walker Board, of 600,000 cubic yards per year. This remarkable drift is seen in the map of the Peacock survey of 1832, in which the westward travel of the sand is shown from 1832 to 1859. The progress of the sand silt has been accompanied by a shoaling up of the harbor until in 1895 the once capacious harbor with its low water depth of 30 feet has shrunk to a mere lagoon with a maximum depth of 17 feet. To open a channel from the canal to deep water the company built a pile and rock jetty 900 feet in length. This was done for the purpose of arresting the westerly drift and enabling them to dredge a channel on its western side. The sand accumulated on the eastern side of the jetty, reached the outer end, flowed past it, and formed the curious tongue which is seen extending past the jetty and almost across the entrance channel. This result shows that while it will be possible to obtain an en-

trance by extending the jetty far out to deep water, the filling in of the beach behind it at the rate of 600,000 cubic yards per year will be perpetual, and the jetty will require to be extended at recurrent intervals. As there is no tidal scour to rely upon, the channel will have to be maintained by the use of dredges. The company's proposition was to build an east pier 3,000 feet long and a west pier about 2,000 feet in length, with an entrance 600 feet in width. The entrance channel, 5,000 feet long, was to connect with an artificial basin 237 acres in extent, dredged out at the Greytown Lagoon to a low water depth of 30 feet. The total cost of the whole scheme, including the harbors, was estimated by the company at $65,084,176.

WORK DONE BY THE COMPANY.—A start in construction was made by the company at the Greytown end. Five large dredges commenced cutting through the alluvial deposits through which the first 9 miles of the canal will be cut. Some 4,500 feet of the canal were cut to a depth of 16½ feet and the canal line through the dense tropical growth was cleared for a distance of 32 miles. A single track railroad was built from Greytown, 11 miles into the interior. The jetty above mentioned was built out 900 feet, and a 17-foot channel dredged from the sea to the Greytown Lagoon.

THE LUDLOW COMMISSION.—The operation of the canal company ceased in 1893 for lack of funds. In 1892 the Senate Committee on Foreign Relations introduced a bill providing for the aid of the United States in the construction of the canal by a guarantee of the bonds issued for construction, and in 1895 Congress appointed a commission consisting of three well known engineers, Colonel Ludlow of the army, Civil Engineer M. T. Endicott, of the navy, and Alfred Noble, a civilian in private practice, for the purpose of reporting on the "feasibility and cost of completion" of the company's project. After examining the route on the isthmus and the engineering data collected by the company, the commission reported that while a ship canal project was feasible, they were unable to indorse several important features of the company's plans. They considered that the data upon which the plans were drawn up was neither sufficiently detailed nor spread over a sufficient period of time to enable accurate conclusions to be drawn, either as to permanence of the proposed structures or the cost of the undertaking as a whole. They considered that the quantities of dredging, excavation, etc., were underestimated, and that the unit prices had been placed too low. They raised the quantities and prices accordingly, and made an estimate of their own which placed the probable cost of completion at $133,472,893, as against the company's estimate of about $67,000,000, an increase of 100 per cent.

The features most severely criticised by the commission were the two great rock-fill dams at each end of the summit level, one at La Flor, 2,000 feet long and 90 feet above the bed of the river, the other at Ochoa, 1,900 feet long and 60 feet above the river bed, and the extension of the canal through the San Francisco basin, where it would be necessary to construct 67 clay dams or retaining embankments, one of which is 1¼ miles in length, and rises 100 feet above the foundations. It was also stated by the board that they found indications of an extreme variation in the level of the lake in wet and dry seasons of 15 feet, and that this variation, extending over an area of nearly 3,000 square miles, represented an enormous volume of water, which it might prove extremely difficult to hold at the desired elevation of 110 feet.

The board suggested that a more thorough examination of the locality might disclose alternative routes which would be free from the objections outlined in their report, and they suggested that $350,000 should be appropriated for a further examination to finish the investigation and prepare final plans and estimates. This recommendation was acted upon, and a new commission consisting of Admiral Walker, Prof. Lewis M. Haupt, and Gen. Hains spent three months in a personal examination of the route and placed in the field a well-equipped force of 250 men, including 80 engineers, a geologist, a hydrographer, ten boring outfits, and a very complete set of apparatus for determining rainfall, evaporation, flow of streams, and all the natural phenomena affecting the construction and maintenance of the canal. The expedition landed in December, 1897, and the observations, plans, and estimates are still in progress, and will not be fully completed for some time.

At a preliminary hearing before a select committee of the Senate the members of the commission roughly estimated the cost of construction as follows: Admiral Walker, $125,000,000; Prof. Haupt, $90,000,000; and Gen. Hains, $140,000,000. In a preliminary report, issued at the close of last December, the commission states that of all the routes that have come up for consideration, the two best are the Maritime Canal Company's route, known as the high level route, and the Lull or low level route. The estimated cost is $124,000,000 for the latter and $125,000,000 for the former. Gen. Hains, however, who is the oldest and most experienced member of the commission, states in a supplemental note to the report that he thinks the estimate should be raised to about $150,000,000.

All these members of the commission "believe that the construction of the canal across Nicaragua is entirely feasible."

RECOMMENDATIONS OF THE WALKER COMMISSION.—Although some time must elapse before the final report is made public, we are in a position to state what will be the general features of the plan finally recommended by the commission. In the first place, the Ochoa dam will be moved up the river to a point above the San Carlos, with a view to eliminating the torrential floods and the silt of that river, which will be allowed to pass away in the ordinary manner through the San Juan.

No attempt will be made to hold the summit level up to the Ochoa dam; but an intermediate dam and a lock will be placed at one of the upper rapids—probably Machuca—and the level will be lowered 20 or 30 feet at that point. This will reduce the height of the Ochoa dam by nearly one-half, and the canal will be carried from Ochoa down the left bank of the San Juan to a point at which it will strike off across the divide in the same manner as, but at a lower level than that proposed in the Menocal scheme. This will increase the cuts but reduce the heights of the embankments, thereby avoiding the risky features of the high level route. This route will be in the nature of a compromise between the high level route of the company and the low level route located by Lull.

The security of the Ochoa dam is further assured by the discovery of solid rock everywhere underlying the bed of the river at the proposed site, and a firm clay has been developed along the site of the embankment foundations. The Menocal idea of using the dams as overflow weirs has been abandoned; separate weirs will be provided in every case.

The commission finds that it can regulate the level of the lake within a recorded fluctuation of 2½ feet above and below the normal. On the west side of the lake, La Flor dam and Tola basin are abandoned. The canal will be cut through the divide to the Rio Grande, and it will be carried down to sea level at Brito by means of locks whose number has not been determined. To assist in controlling the lake level and relieving the duty thrown upon the San Juan, it is not unlikely that the canal through the western divide will be given considerably greater width to enable it to assist in carrying off the surplus waters in the seasons of flood.

The least depth throughout the canal will be 30 feet. All excavated channels will be given extra width both in the river and lake, while the curvature will be eased to render navigation less difficult. All locks will be of a length and depth to accommodate the increased dimensions of modern steamships.

Finally, the commission is of the opinion that while the rainfall is excessive (22 feet on the eastern section), the material will stand up remarkably well in excavation. Moreover, the climate, on account of the prevailing trade winds, is not unhealthy, and it is not apprehended that it would prove a hindrance to the prosecution of the work. The estimated time for completion is from eight to ten years.

REPORT OF THE ISTHMIAN CANAL COMMISSION.

THE report of the Isthmian Canal Commission is the record of by far the most costly and complete investigation of the Isthmian Canal problem ever carried out. The Commission is made up of some of the most eminent engineers in army and civil life; it has spent three years of time and over one million dollars of money in examining the Panama, the Nicaragua and every other possible route across the Isthmus; it has visited every canal of importance in Europe; under its direction thirty-one engineering parties have been employed in a survey of the isthmus as follows: 150 engineers and assistants at Nicaragua, 20 engineers and assistants at Panama, 50 engineers and assistants at Darien.

The report says that a tide level canal at Darien would involve a 4.2-mile tunnel, and would cost $289,770,000, while canals on three alternative routes at Caledonia would cost from $263,340,000 to $320,040,000. Dismissing these as financially impracticable, the report discusses the Panama and Nicaragua routes in very elaborate details. A digest of this portion of the report follows:

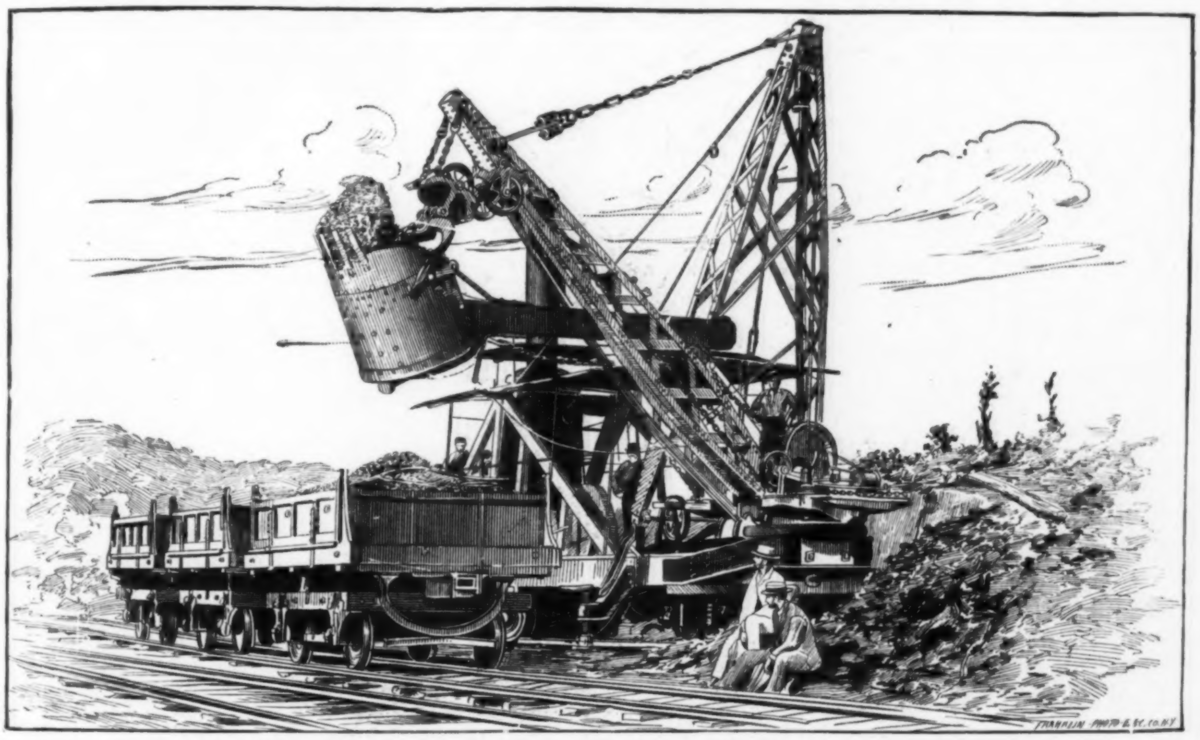
THE PANAMA ROUTE.

The natural attractions of the Panama route lie in the combination of a very narrow isthmus with a low summit. The width of the isthmus is less than 36 miles in a straight line, only 5 miles more than at San Blas, the narrowest place, while the original summit was less than 300 feet above tide water, which, though higher than the Nicaragua summit, is less than half the height of any other summit which has been investigated. Furthermore, the high portion of the isthmus is limited to a width of about 6 miles near the Pacific side, and the Chagres River affords canoe navigation from the Atlantic to within 16 miles of the Pacific.

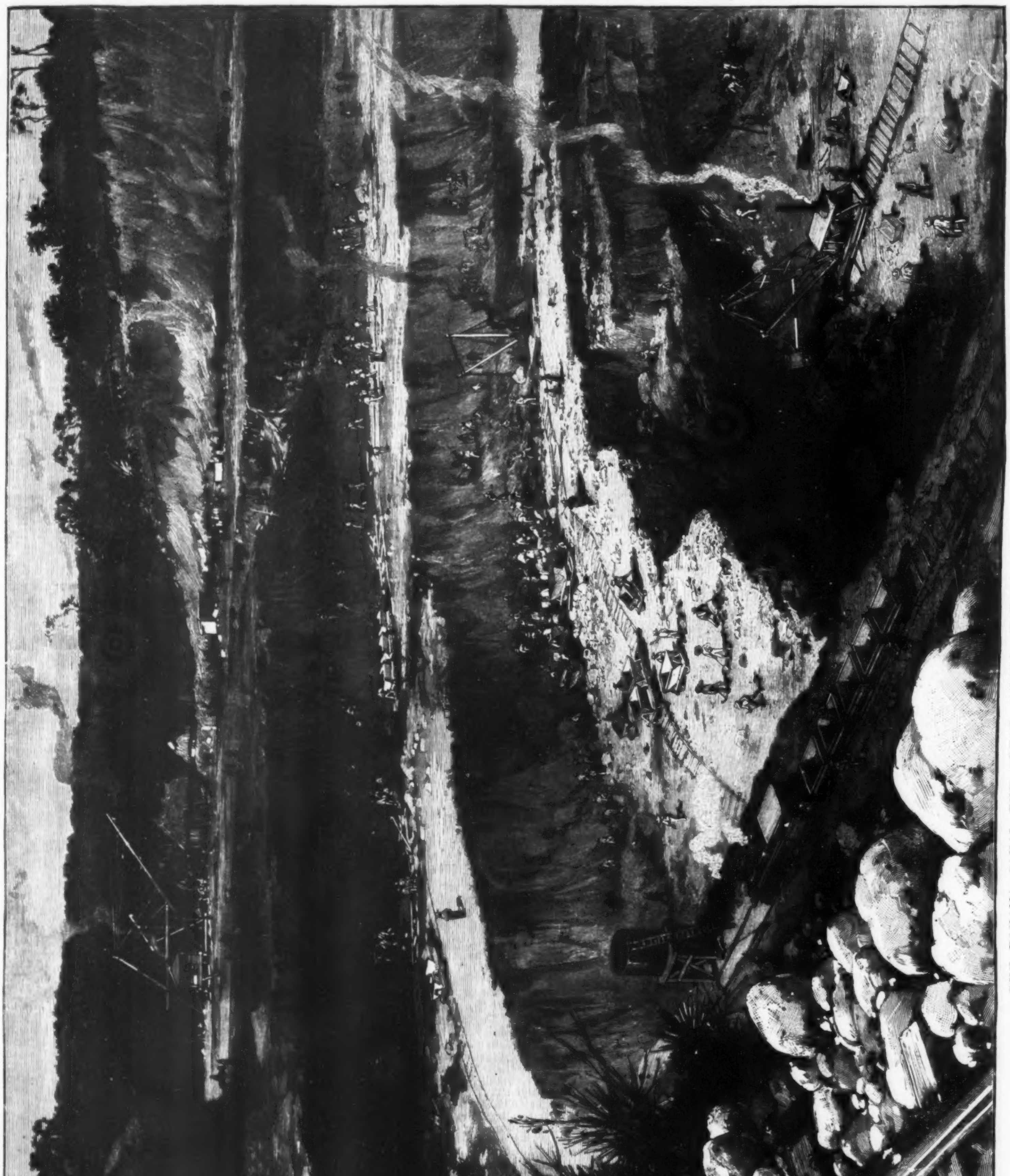
The isthmus here runs nearly east and west, but the course of the railroad or canal is from northwest to southeast, the Pacific terminus being about 22 miles farther east than the Atlantic terminus. The Atlantic port is Colon, and the Pacific port Panama. At Colon the mean tidal range is about 1 foot; at Panama it is about 20 feet. The harbors are not of the first class. They have served the demands of a limited commerce heretofore. Some improvements at Colon would be necessary if the canal should be built. The defect of the Colon Harbor is that it is exposed to "northers." When these are severe, ships are now compelled to go to sea. This may occur once or more each year. Panama Harbor is a roadstead behind islands at the head of a great bay or gulf. For the terminus of a canal it is sufficient, as the stay of vessels is expected to be short.

PHYSICAL DATA AVAILABLE.

The old Panama Canal Company began its work without adequate knowledge of the physical conditions at the isthmus. It inaugurated at an early day some of the surveys and examinations required to supply the deficiency, and some of these it maintained as long as it continued to exist. Additional surveys were made by the liquidator, and very extended additional surveys and observations have been made by the new company. The information relating to the topography, hydrography, and geology of the isthmus is now much more complete than is usual before inauguration of an engineering enterprise in a new country. The canal company spared no trouble or expense in laying it all before the Commission. The most important maps, drawings, and documents were lithographed or printed and systematically arranged for the use of the Commis-



EXCAVATING PLANT AT PANAMA—OSGOOD AMERICAN EXCAVATOR.



THE PANAMA CANAL—THE GREAT COLIMA CUTTING IN 1886.

sion, copies being furnished for each member. Many other documents were supplied in manuscript. In all some 340 documents, many of them elaborate studies, were furnished. These supplied essentially all the data required for the preparation of plans and estimates, though further information was desired as to the foundation upon which the great dam at Bohio must be built, and as to the area of the Chagres River drainage basin. This additional information was obtained by the field parties of this Commission. It was necessary also for the purpose of this investigation to verify the French data. Independent lines of levels, measurements of distances, borings, soundings, and hydrographic observations made by its own parties, supplemented by personal observation, enable this Commission to state that the data furnished by the canal company are essentially correct.

LAKE BOHIO.

No location suitable for a dam exists on the Chagres River below Bohio, and while this location is not without difficulties it has the great advantage that about 3 miles southwest of the dam, near the head of the Rio Gigante, a tributary of the Chagres, there exists an excellent site for a spillway, by which the discharge from the lake can be kept well away from the dam and accessory works, and may be made extremely large without inconvenience either to the canal itself or to the country below the lake. The height of this spillway would regulate the height and area of the lake. After careful consideration of the requirements for flood control and for storage against deficiency in the dry season, and also of the effect upon the amount of excavation required for the canal through the continental divide, the Commission has decided to fix this height at 85 feet above mean tide, and to make the spillway a fixed weir 2,000 feet long. The area of the lake at this height is 38.5 square miles, or 1,073,318,400 square feet. Using coefficient 3.5 in the weir formula, it is computed that with a depth of 5 feet over its crest the weir will discharge 78,260 cubic feet per second. In reaching elevation 90 the area of the lake will be enlarged to about 43 square miles and it will impound over 5,680,000,000 cubic feet of water. The quantity of water discharged over the weir while the lake is rising from elevation 85 to elevation 90, assuming circumstances of flow similar to those observed in the flood of 1893, is computed to be about 4,000,000,000 cubic feet. The total quantity of water impounded and discharged before the lake will rise above elevation 90 is therefore nearly 10,000,000,000 cubic feet. It provides for unimpeded navigation during all floods not exceeding 75,000 cubic feet per second. The velocity of the currents in the narrowest part of the lake would not exceed 2 feet per second. Floods may occur, however, which will cause the lake to rise above elevation 90. From the data available it is not possible to compute with precision the exact height which a flood may hereafter attain, but the extreme possible effect of a flood discharging 140,000 cubic feet per second for a prolonged period would be to raise the water over the spillway to 92.5 feet. All great floods are of short duration, and such a flood is absolutely without precedent, being as improbable as any other convulsion of nature. The crest of the dam has, however, been placed at 100 and the top of the lock walls and gates at 94, to make them entirely safe from overflow by even such a flood, the ill effect of which would be limited to the temporary obstruction of navigation by swift currents in the narrowest part of the lake, where the velocity might reach 5 feet per second. Under extreme conditions the lake might be lowered to 82 to provide water for operating the canal during the dry months. The excavations will be so adjusted as to give a depth of 35 feet at that level. This provision for the storage of water for use in the dry season is ample for a traffic of 10,000,000 tons per annum in vessels of the size now in common use. It will be equally ample for a much larger tonnage if, as seems probable, the size of vessels continues to increase. For example, the number of vessels which passed the Suez Canal in 1900 was 3,441, against 3,389 in 1890, while the gross tonnage in 1900 was 13,699,238, against 9,749,129 in 1890. The number of vessels in 1900 was less than in 1898, while the total tonnage was greater. The annual flow of the Chagres and the topography of the country are favorable, however, to a very large increase of the supply, if that be found desirable in the future. A reservoir can be constructed at Alhajuela with a capacity for storing an additional volume of water four times that now provided for daily consumption.

The overflow of Lake Bohio will discharge through the Gigante spillway into Pena Blanca Swamp, thence through natural and artificial channels to the Chagres River below Gatun, and thence through that river to the sea, being kept out of the canal in the lowlands by levees where necessary.

DETAILED DESCRIPTION.

The canal, as thus projected, may be described as follows:

Beginning at the 6 fathom line in Limon Bay, a channel 500 feet wide at bottom, and with side slopes 1 on 3, is excavated, curving gently to the left upon a radius of 6,560 feet, until it reaches a point just inside the jetty constructed by the old Panama Canal Company. Here it changes direction to the right upon a curve of 3,280 feet radius, and is then conducted upon a straight line for a distance of 2,000 feet to a point 2.39 miles from deep water in the bay. For about a mile this wide channel is inside the shore line, forming a narrow but well-protected harbor. Near the apex of the second curve the bottom width is increased to 800 feet for a length of 800 feet, to provide a turning basin.

COLON TO BOHIO.

From the inner end of the harbor the bottom width of the canal is 150 feet, the side slopes of 1 on 3 being retained for 1.86 miles through the swamp, after which they are reduced to the standard used in firm earth, and are kept at that standard for a distance of 12.56 miles farther to the Bohio locks. The length of this level measured from the inner end of the harbor is 14.42 miles.

BOHIO LOCKS.

At Bohio is located a double flight of locks, having a total lift varying from 82 feet at the minimum level of the lake to 90 feet at the maximum, 41 to 45 to each lock, the normal lift being 85 feet. These locks are on the location adopted by the French company. They are of the type adopted for both the Nicaragua and Panama canals and described elsewhere in this report.

LAKE BOHIO.

Above the locks the canal enters the artificial lake formed by the Bohio dam and known as Lake Bohio. For the first 7 miles it is a broad, deep body of water, affording room for anchorage, as well as navigation. Beyond this some light excavations are necessary. At the upper end the channel will be enlarged to provide for the flood discharge of the Chagres, being given a minimum section of 42,000 square feet. The length of the channel in Lake Bohio is 12.68 miles from the locks to the point where the canal leaves the Chagres. The section extends ninety-three hundredths of a mile farther, to the point where it enters the cut through the divide.

OBISPO GUARD GATES.

Near the entrance to the summit cut will be placed a pair of gates 100 feet wide, so that if it should become necessary to draw off the water from the summit cut the level of Lake Bohio would not be affected. These gates will be at the site of a lock proposed by the French company near Obispo, with a foundation on hard rock.

CULEBRA CUT.

The summit cut is 7.91 miles long from the Obispo gates to the Pedro Miguel locks. The highest point is about 5 miles from the Obispo gates, where the bottom of the canal at the axis is 286 feet below the natural surface of the ground. This is the famous Culebra cut, though the name has often been applied only to the mile of heaviest work. There is a little very hard rock at the eastern end of this section, and the western two miles are in ordinary materials. The remainder consists of hard indurated clay, with some softer material at the top and some strata and dikes of hard rock. In fixing the price it has been rated as soft rock, but it must be given slopes equivalent to those in earth. This cut has been estimated on the basis of a bottom width of 150 feet, with side slopes of 1 on 1. While the cut would probably not be finished with this uniform slope, this furnishes as correct a basis of estimate as can now be arrived at. The entire cut will be lined with masonry walls, finishing at elevation 92, 2 feet above high water, these walls having nearly vertical faces and furnishing benches 38 feet wide on either side of the canal, on one of which the Panama Railroad will be laid, while it is probable that a service track will be placed on the other.

Much has been said about the instability of the Culebra cut; in point of fact, there is a clay in the upper portion of the deep cut which flows readily when saturated, but which will give little trouble if thoroughly drained; probably nine-tenths of the material would naturally be classed as hard clay of stable character; it would weather somewhat, and the surface might require some repairing with concrete in bad places, a practice common in deep cuttings in Europe. This clay disintegrates rapidly in water, and for this reason the canal prism should be confined between masonry walls. With the provision made for broad benches on each side, on which any slight slides would be arrested, it is believed that no trouble will be experienced.

PEDRO MIGUEL LOCKS.

The Pedro Miguel locks will be similar to the Bohio locks, the aggregate lift varying from 54 to 62 feet. A level of 1.33 miles long extends from the Pedro Miguel locks to the last lock, which is at Miraflores. The normal elevation of the surface of the water is 28.

MIRAFLORES LOCK.

At the end of this level will be located the Miraflores lock, with a lift varying from 18 feet at high tide to 38 feet at mean low tide. There is a good rock foundation for this lock. A spillway will be required to regulate the height of this level.

PACIFIC MARITIME SECTION.

For 4.12 miles beyond the Miraflores lock the canal extends through a low swamp country through which the Rio Grande runs. Occasional rock is found here, but the material is generally very soft and the canal has been estimated for a bottom width of 150 feet with slopes of 1 on 3. This brings the canal to a point known as La Boca where the Panama Railroad Company has constructed a large and substantial wharf. A dredged channel 200 feet wide with slopes of 1 on 3 will extend from this point 4.41 miles to the 6-fathom line in Panama Bay. The first 2 miles of this dredged channel are through flats which are bare at low water, where there is a considerable amount of submerged rock.

BOHIO DAM.

The Bohio dam is the most important structure on the line, being of great magnitude, of vital necessity to the scheme, and offering many difficulties of construction. The Commission has devoted much time to the procurement of full and reliable information concerning the foundation upon which this dam must rest, and to study the various types of structures which might be adopted.

The borings made by the French engineers upon and near the line of the dam as furnished to the Commission were 21 in number. In the central part of the valley they did not go down to rock. In this case the Commission decided to do more than verify the data furnished to it, and caused a large number (86) of additional borings to be made. With the exception of seven, which were abandoned before completion on account of accidents to the apparatus or unusual difficulties of soil, all of these borings reached rock. They show a variety of materials—hard clay, soft clay, sand, gravel, and some mixtures of sand, clay and gravel in varying proportions. These materials are found in beds of varying shape and thickness, not distributed with uniformity and not arranged according to any general law from which can be deduced the character of the soil at points other than those actually examined. In every section constructed from the borings, strata of greater or less dimensions are found, which are permeable by water. A masonry dam founded throughout upon the rock, or an earth dam with a masonry core going down everywhere to rock, would close the valley completely and would leave no question open as to its future efficiency. In its preliminary report, the Commission based its estimates on a masonry dam. The examination of the ground had not at that time been completed. So far as they had progressed they showed a site where a masonry dam seemed the most suitable, but it was subsequently found that the depth to rock upon that site was at least 143 feet below sea level at the deepest part. It was considered best to avoid, if possible, so great a depth of foundation. A site was found a few hundred feet farther downstream where the length of the dam would be considerably greater than at the former site, but the greatest depth to rock revealed by the borings was only 128 feet below sea level. The physical features of the location admit of the construction of an earth embankment with a heavy masonry core carried down to bed rock throughout the length of the structure. For reasons of economy that type of dam is preferable to one wholly of masonry upon the new site, and is now adopted.

It is proposed to sink the foundation of the core wall by the pneumatic process at all points where the foundation bed is lower than about 30 feet below mean sea level. This requires pneumatic process to be used through a length of 1,314 feet, of which about 310 feet is at the maximum depth of 128 feet below the sea level. Where the foundation bed is above elevation 30, cofferdams are to be used. This involves the use of coffer-

EXCAVATING PLANT AT PANAMA—FRENCH EXCAVATOR, "DOWN DIGGER" TYPE.

dams through a length of 324 feet, the foundation at sea level being extended 78 feet at the easterly end and 246 feet at the westerly end of the pneumatic work. The cofferdams extend to a height 8 feet above sea level. Above elevation 8 all operations would be carried on by the ordinary methods of dry work.

The width of the dam at the top is 20 feet, and its total length is 2,546 feet. The elevation of the top is 100 feet above mean sea level, affording a superelevation of the dam of 8 feet above the highest possible water in the lake and 10 feet above the usual high water. Its total height above the lowest part of the foundation is 228 feet. The earth faces of the dam are designed to have mean slopes of one vertical to three horizontal, and to be broken by three terraces, each 6 feet wide. It is necessary to pave only the upstream face, but it is probable that both faces would be heavily riprapped with the rock spoil from the lock excavation near the westerly end. The masonry core is 30 feet thick at and below elevation 30. From that level it tapers to a thickness of 8 feet at top.

Material for the heavy fill required is found in the immediate neighborhood. The local conditions are such that not less than seven-eighths of the work could be completed without interfering with the natural flow of the Chagres. When it becomes necessary for the completion of the dam to divert the river, the unfinished Gigante spillway and, later on, the finished locks at Bohio may be employed as diversion channels.

GIGANTE SPILLWAY.

The Gigante spillway, which is a structure of considerable magnitude, is very simple. There is a good rock foundation at or above tide level for the entire length of this spillway. It will consist of a dam entirely of concrete with a crest at elevation 85, terminating in an apron at elevation 65, with a solid foundation below this level, the apron being everywhere below the present surface of the ground. The foundation, below elevation 65, will be put in first and before the flow of water through the present river at the site of the Bohio dam is checked. The estimated cost, including the channel ways immediately above and below it, is $1,209,419.

PANAMA RAILROAD DIVERSION.

From Bohio to the Obispo gates the Panama Railroad must be rebuilt for 15.5 miles on a new location, with a bridge across the Chagres below Gamboa. An estimate made from approximate profiles indicates that the cost of this diversion will not exceed $75,000 a mile, or $1,162,500. From the Obispo gates the railroad will be carried for 6 miles on the bench formed by the retaining wall on the east side of the Culebra cut, these 6 miles being estimated to cost $10,000 a mile, which includes only track laying, ties and ballasting. Beyond this will be a mile of light work estimated at $25,000, while the main track will have to be raised for 2 miles farther at a cost of $20,000. Combining these figures, the total cost of the diversion of the Panama Railroad becomes $1,267,500.

Summing up, the total estimated cost of completing the Panama Canal is as follows:

Total estimated cost.	Miles.	Cost.
Colon entrance and harbor	2.39	$8,057,707
Harbor to Bohio locks, including levees	14.42	11,099,839
Bohio locks, including excavation	.35	11,567,275
Lake Bohio	13.61	2,952,154
Obispo gates		295,434
Culebra section	7.91	44,414,460
Pedro Miguel locks, including excavation and dam	.35	9,081,321
Pedro Miguel level	1.39	1,192,286
Miraflores locks, including excavation and spillway	.20	5,781,401
Pacific level	8.53	12,427,971
Bohio dam		6,369,640
Gigante spillway		1,209,419
Pena Blanca outlet		2,448,076
Chagres diversion		1,929,982
Gatun diversion		100,000
Panama Railroad diversion		1,267,500
Total	49.09	$120,194,465
Engineering, police, sanitation, and general contingencies, 20 per cent		24,038,893
Aggregate		$144,233,358

The total amount of excavation is 94,863,703 cubic yards, exclusive of excavation for the Bioho dam and the Gigante spillway.

LENGTH AND CURVATURE.

The location of the canal is, in general, the same as that proposed by the French company. Its total length, from 36 feet deep in the Atlantic to 36 feet deep in the Pacific, is 49.09 miles. The distance from the inner end of the harbor enlargement at Colon to the shore end of the bay channel at La Boca is 42.3 miles, of which 11 miles is the broad channel of Lake Bohio. The alignment is exceptionally good, the sharpest curve having a radius of 6,232 feet, except one at the entrance to Colon Harbor, which has a radius of 3,280 feet, but where the bottom width is from 500 to 800 feet. The total curvature in the entire length of the canal is 771 deg. 39 min.

TIME OF TRANSIT.

The time required to pass through the canal after completion will vary with the size of the vessel and with the number of other vessels. For the purpose of comparison the time has been carefully computed for a ship 400 feet long, 50 feet beam and 24.5 feet draft, or what may be called an averaged-sized ship. The open sea speed is taken at 12.5 statute miles, or about 11 knots per hour. The reduced speed in various parts of the canal and the delays caused by lockages and by passing other vessels have been obtained from observation of the practical working of the Sault Ste. Marie and the Manchester canals. They are as follows: In canal sections having a bottom width 150 feet, speed on tangents 8 miles per hour, on curves 7 miles per hour; in Panama Bay channel, speed 9 miles per hour; in Lake Bohio, speed on tangents 10 miles per hour, on curves 9 miles per hour; in harbors and harbor entrances, speed on tangents 10 miles per hour, on curves 8½ miles per hour; all statute miles. The delay caused by lockages is 3 hours and 58 minutes, and that caused by meeting other vessels, 1 hour and 14 minntes. From these data the time of transit through the canal is computed to be 11 hours and 14 minutes

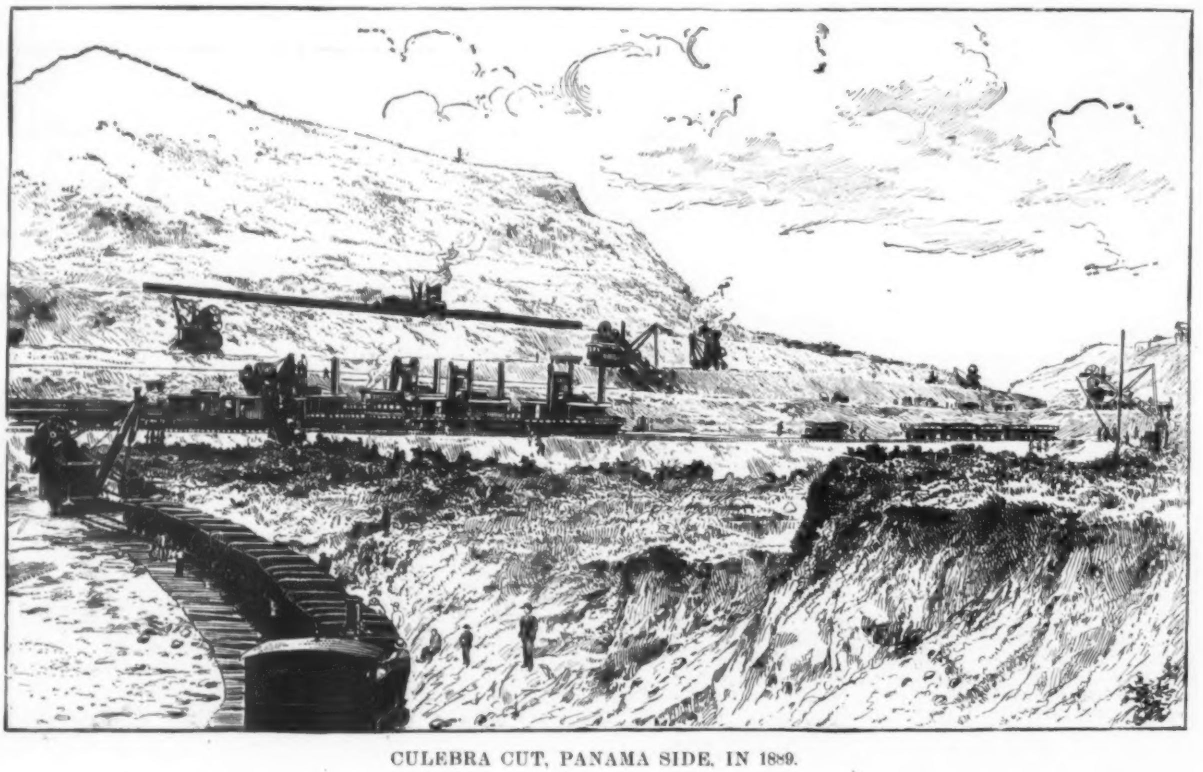
The plan recommended by the Commission is, in its general outlines, the same as the second plan of the French engineers, the one preferred by them, except for the time required for construction. The principal difference is in the height given to the Bohio dam and the important consequences which result therefrom. A marked feature of the Commission's plan is its simplicity. The increase in the depth and area of Lake Bohio renders it possible to receive the full flood discharge of the Chagres directly into it without impeding navigation and at the same time to take full advantage of favorable topographical features of the country in the subsequent discharge of the surplus waters. The Alhajuela dam becomes unnecessary for flood control, and its construction may be deferred until additional storage capacity is required as a result of a large increase in the traffic of the canal in the future. The outlet of Lake Bohio becomes a single fixed weir instead of two weirs with regulating gates and with two separate channels to the sea. A great reduction also results in the amount of excavation required to cut through the continental divide. There is a material reduction of cost.

TOTAL VALUE OF THE PANAMA CANAL.

Summing up, the total value of the property of the new Panama Canal Company is found to be:

Excavation already done	$27,474,033
Panama Railroad stock at par	6,850,000
Maps, drawings and records	2,000,000
Total	$36,324,033

To which add 10 per cent to cover omissions, making the total valuation of the Panama Canal $40,000,000.



CULEBRA CUT, PANAMA SIDE, IN 1889.

THE NICARAGUA ROUTE.

The Nicaragua route attracted the attention of explorers in the early days of interoceanic canal discussion, and was regarded by many as a most favorable one. Water communication by means of a large river and lake from the Atlantic to within a short distance of the Pacific accentuates the natural advantages of this route and at the same time tends to exaggerate them and to obscure the attendant difficulties.

Lake Nicaragua is about 103 miles long. It has a maximum width of about 45 miles and an area of about 3,000 square miles. It is fairly regular in outline, with its longer axis nearly parallel to the Pacific coast, which in this vicinity has a northwesterly direction. It resembles Lake Erie somewhat in shape, but has only about one-third the area of the latter. Notwithstanding the fact that the existence of this lake had long been known, it appears that the first instrumental survey was made by the Nicaragua Canal Commission in 1898. It was then found that the bottom of the lake is about sea level over the greater part of its area, a comparatively small depression being below that level. The maximum depth is about 200 feet, and is found just south of the island of Ometepe, which has an elevation of 5,000 feet.

The surface of Lake Nicaragua is generally a little more than 100 feet above sea level. Its extreme fluctuation is not definitely known. Its annual fluctuation varies with the annual rainfall and the discharge of the streams that empty into it. These are small, and in the dry season they discharge very little. Mr. Menocal in his report for 1885 states that the lake was as high as 110.63 feet above mean sea level at the end of the wet season of 1878. This is perhaps founded on the observations of the residents of Granada, who are reported to have seen the water of the lake up to the top of the steamboat wharf at that place. This may be regarded as an approximate determination of highest lake level. The data for fixing the minimum level of the lake are equally uncertain; but it is stated on the authority of what are believed to be competent witnesses that it has been as low as 97 or less. These extremes have only been reached at long intervals. The fluctuations in the last three years, during which time regular observations have been taken, have amounted to only 6.09 feet.

The San Juan River, through which the lake discharges at Fort San Carlos, follows a tortuous course in a southeasterly direction and empties through several mouths into the Caribbean Sea near Greytown. The distance from the lake outlet to the mouth of the river is about 80 miles in an air line, but about 120 miles following the windings of the river, the greater portion of the valley drained being on the right bank, where the divide, a lofty mountain range, is about 50 miles distant. On the left bank the divide is only 10 to 20 miles from the river, and the crest is much lower. The Indio, which empties into the Caribbean Sea some 6 miles northwest of Greytown, runs generally parallel to the San Juan, the headwaters of some of its tributaries being only about 15 to 20 miles distant from that river.

The largest and most important tributary of the San Juan is the San Carlos. It rises in the mountains of Costa Rica, flows northeasterly and empties into the San Juan about 57 miles (measured along the windings of the river) from the lake. It is a wide, swift stream, having a drainage area of about 1,500 square miles, as determined from the best maps available. This estimate may be too great or too small, as the region has never been surveyed. The discharge varies within wide limits. It is known to have been as low as 3,000 cubic feet per second, and as high as 66,820 cubic feet per second. The estimated possible maximum is 100,000 cubic feet per second.

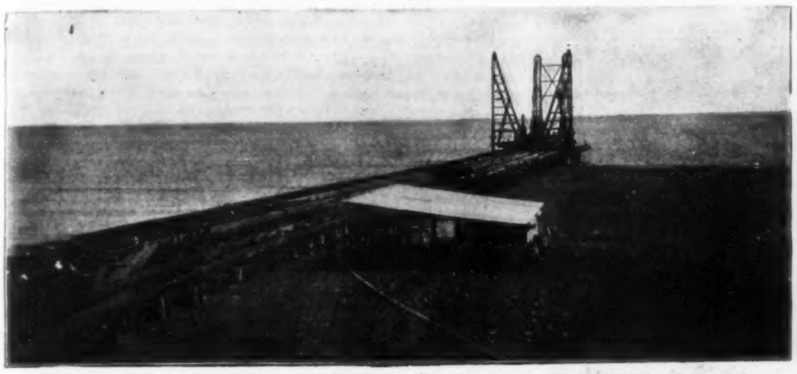
RAINFALL.

Along the Atlantic coast in the vicinity of Greytown and for some distance inland the rainfall is the greatest known on the continent. There is no definite dry

season. Rain may be expected almost any day in the year. On the other hand, the entire drainage basin of Lake Nicaragua lies in a region having a well-defined dry season. The annual rainfall near Grey Town sometimes amounts to nearly 300 inches. The average is probably 260 to 270 inches, while at Bluefields, 75 miles to the north, and at Port Limon, 70 miles to the southeast, it is less than half as much. There is a perceptible diminution in the annual rainfall as one proceeds westward to the lake. The total for the year 1899 at Grey Town was 285.93 inches, while that for the same period at Ochoa was 177.91 inches, and at Fort San Carlos 77.20 inches. For the year 1900 the annual rainfalls were for Grey Town, 276.10 inches, for Ochoa, 158.83 inches, and for Fort San Carlos, 89.34 inches. The heaviest observed rainfall in a short period was that at Silico station on Lake Silico, November 4, 1899, when 10.5 inches fell in six hours, an average of 1¾ inches per hour. On the same date a fall of 12.48 inches in twenty-four hours was observed at Grey Town. A rainfall of 4 inches or more in one day is not a rare occurrence in that vicinity. In the drainage basin of Lake Nicaragua the average annual rainfall is about 65 inches.

PROJECT OF ISTHMIAN CANAL COMMISSION, 1901.

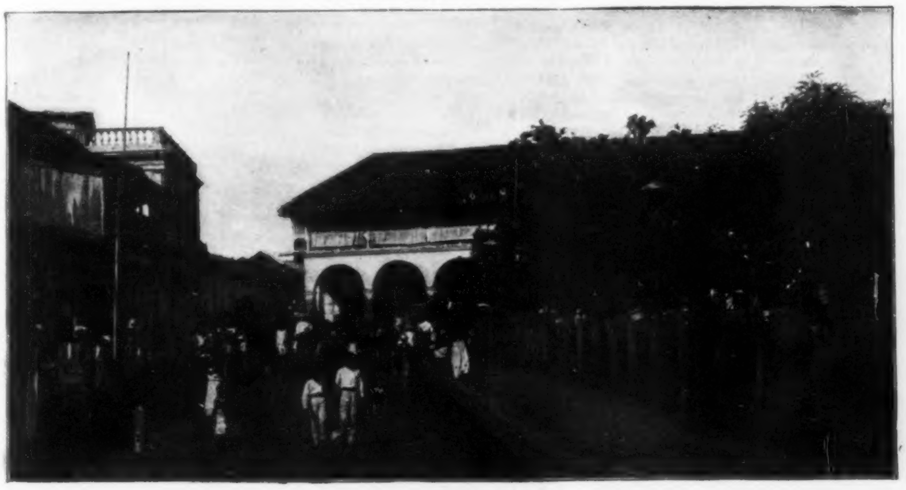
The project of the Isthmian Canal Commission follows the general route of that proposed by the Nicaragua Canal Commission, but the depth of water in the canal has been increased, the locks duplicated and en-



THE JETTY AT GREYTOWN, LOOKING NORTHWEST—SHOWS ACCUMULATION OF DRIFTING SAND AGAINST EAST SIDE OF JETTY.

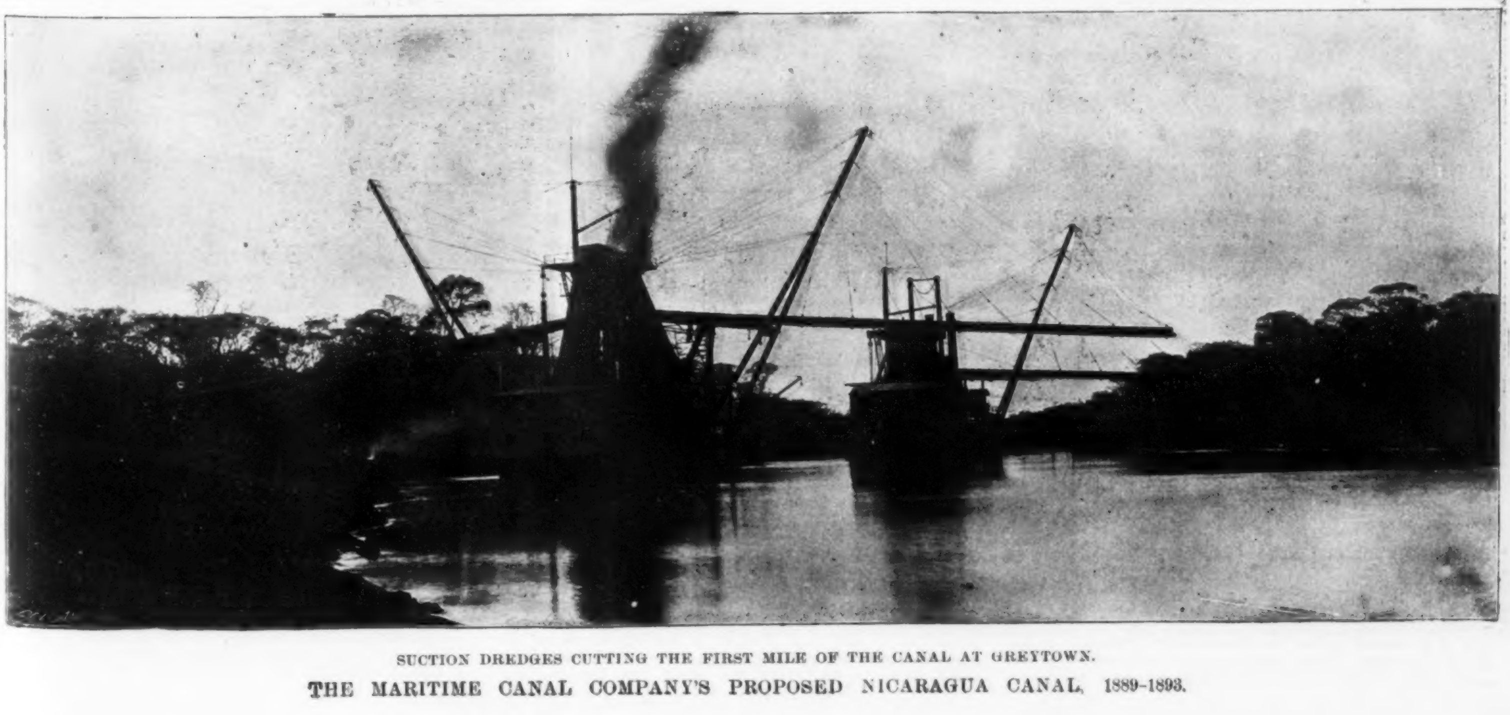
CORDUROY FOUNDATIONS FOR RAILROAD FILL ACROSS THE SWAMP.

CASTILLO, LOOKING UP THE SAN JUAN—OLD SPANISH FORT ON THE LEFT; RAPIDS TO THE RIGHT.



THE MARKET IN GRANADA, NICARAGUA.

VIEW ON THE SAN JUAN RIVER AT MOUTH OF THE RIVER SAN FRANCISCO.



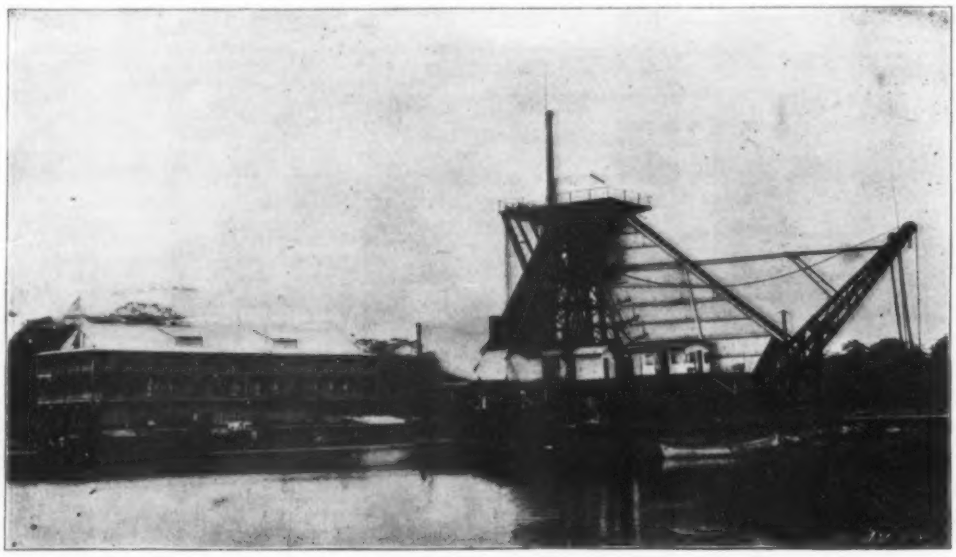
SUCTION DREDGES CUTTING THE FIRST MILE OF THE CANAL AT GREYTOWN.

THE MARITIME CANAL COMPANY'S PROPOSED NICARAGUA CANAL, 1889–1893.

larged, and a new and better site for a dam in the San Juan found. The project is as follows:

GREY TOWN HARBOR AND ENTRANCE.

Beginning at the 6-fathom curve the entrance to the canal will lie between two jetties running nearly north and south, about 1¾ miles northeast of Grey Town and passing close to the most westerly bend of the lower San Juan, near its entrance to Harbor Head Lagoon. The entrance to the harbor is to be 500 feet wide and not less than 35 feet deep at low water. At the shore end of the jetties the line swings to the right on a curve of 4,175 feet radius and then passes into a tangent across the existing Grey Town Lagoon. For a distance of 2,500 feet from the inner end of this curve the width is continued at 500 feet. It is then widened to 800 feet for a further distance of 1,000 feet, in order to furnish a turning basin. It is then gradually reduced to 150 feet, the regular width of canal at the bottom. This width is reached 2.15 miles from the 6-fathom curve in the Caribbean. The head of the east jetty is to extend to this curve and is the zero point to which distances along the canal are referred. The harbor thus formed is well protected. The estimated cost of the entrance and harbor is $2,198,860.



MARITIME CANAL COMPANY'S STOREHOUSE AND DREDGE AT LA FE, GREYTOWN.

SECTION FROM HARBOR TO LOCK NO. 1.

From the harbor the line runs in a southwesterly direction, crossing the San Juanillo to the low, swampy ground along the Rio Misterioso. At a distance of 7.56 miles from the entrance the line swings to the left on a curve of 11,459 feet radius, and then follows a straight line in a direction a little west of south through the first lock, which is located 9.59 miles from the entrance.

Lock No. 1 is located in a hill on the southwest side of the Misterioso, and will have a lift of 36½ feet above mean low tide. This lock, as well as all others, will be in duplicate and founded on rock. The swamps communicate freely with the San Juan River through the San Juanillo and other streams, and the flood level rises at lock No. 1 to about 11 feet above sea level.

It is proposed to exclude flood water from the canal on this section. This will require embankments on both sides. They are to have a minimum top width of 15 feet, with side slopes of 1 on 3. The crest of the embankments will be 5 feet above the highest flood levels. These dimensions apply to all sections of the canal where embankments are required.

SECTION FROM LOCK NO. 1 TO LOCK NO. 2.

From lock No. 1 the line continues in the general direction of the Misterioso for about 2 miles. It then crosses the Pescado, which drains a swampy region to the southward, and enters the region drained directly into the San Juanillo. It crosses this stream about 2 miles from the place where the San Juanillo leaves the San Juan, and then traverses about a mile of swamps and low hills, passing into the valley of the Rio Negro, a tributary of the San Juanillo, behind the hills at Punta Petaca, where it is about 1 mile distant from the San Juan. It then continues in the valley of the Rio Negro, crossing it about a mile east of the Negro hills in which lock No. 2 is located. There are two curves on this section, each of 8,594 feet radius. The section is generally swampy, but in the Rio Negro Valley the line cuts through some hills.

The canal surface in this section is to be maintained at a minimum elevation of 36 feet above mean tide. The flood levels immediately above lock No. 1 appear to be about 31 feet above the same reference and immediately below lock No. 2 about 43 feet above it. The region communicates freely with the San Juan during high water in the latter, whence most of the flood water comes, and also receives considerable drainage from the mass of hills north of the line. The embankments have not only to maintain the canal level, but are also required to exclude floods from the San Juan on the upper portion of the section. On the north side of the canal hills form the greater part of the line of protection, although a few swamps have to be crossed by embankments. On the south side the Silico hills protect the level for several miles, but to the westward of them are long stretches of swamp with soft bottom where embankments are required. These embankments constitute one of the difficulties of this section. The estimates provide for the removal of the soft material for a width of 30 feet at bottom to make the embankments safe when built. They are located in most places so far from the canal line that the material excavated would not be available even if suitable, which it seldom is. They will be formed from clay borrowed from the hills.

The swamp level near lock No. 1 is at about elevation 16, and at lock No. 2 about elevation 38. Almost the entire area within the embankment lines (some 12 or 13 square miles) will be below the level of water in the canal. The total drainage tributary to the section is probably 25 square miles. A waste way is required which will be located at or near the Silico hills where the flood level in the San Juan is below the canal level. It is to be a simple overflow weir with crest at elevation 36, the minimum canal level, and to have a length of 600 feet, which will prevent the canal level rising above elevation 37.5. The assumed maximum rainfall is 12 inches in twelve hours, all reaching the pool within twenty-four hours. No site with rock foundation has been found for this waste way. It will be built in the clay hills. Lock No. 2 will have a hard rock foundation. The lift will 18½ feet, from elevation 36 to elevation 54.5.

The length of this section is 10.96 miles. A part is through swamps, requiring side slopes of 1 on 3. In the remaining portion the cross section is reduced to the standard adopted for firm earth.

SECTION FROM LOCK NO. 2 TO LOCK NO. 3.

The general direction of the line in this section is a little north of west. It leaves the Rio Negro Valley near lock No. 2, and passes behind the Serapiqui hills, which were formerly supposed to be connected with the high range to the northward. At this point the line is more than a mile from the San Juan. A short distance farther west the route crosses the Tamborcito ridge, after which at short intervals it crosses the Tambor Grande and San Francisco ridges. A line located around the ends of these ridges near the river would have inadmissably sharp curvature, and would be liable to injury during river floods. If carried across them far from the river the cuttings would be very heavy. The line projected by this Commission is at a safe distance from the river, and although involving heavy work, avoids the much heavier work that a location farther from the river would require. The deepest cut on the center line of the canal is 297 feet, in the Tamborcito ridge.

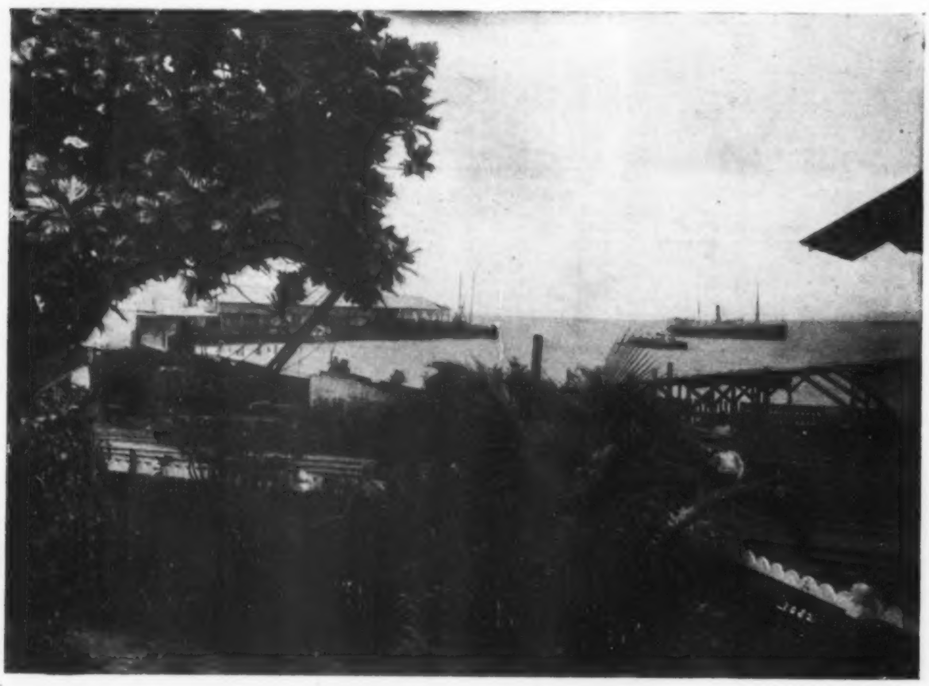
Riprap protection against river floods will be required in the swamp levels of those localities where the line approaches close to the river. After crossing the San Francisco River the line follows a westerly direction to the Danta, which it first crosses about 2 miles from the San Francisco. It then follows the valley of the Danta, which it crosses several times, to lock No. 3. This portion of the line passes through a swampy region with occasional low hills.

The cut in the Tamborcito ridge is the deepest on the route, and will consist largely of hard, basaltic rock. It is, however, only about 3,000 feet from the foot of the ridge on the east side to the foot on the west, and the crest is narrow.

There are eight curves on this section of the canal, of which one has a radius of 4,911 feet, four of 5,730 feet, one of 6,876 feet, one of 8,594 feet, and one of 11,459 feet.

Since the line was laid out borings have shown that deep sand exists under a part of that portion of it lying between the Tambor Grande and the San Francisco, its upper surface being near the canal bottom. It is probably a former bed of the San Juan River. Recent surveys and borings have shown that this material can be avoided by a location farther inland, but as it has not been practicable to take new borings across the ridges on the new lines, the estimates are made on the line that is laid down, and include an allowance for puddling the bottom of the canal where needed. A small amount of permeable material is also shown by the borings in a hill crossed by the canal line near the Florida Lagoon, and the estimates provide for puddling at this locality.

The surface of the swamp near lock No. 2 has an elevation of about 38 feet above the sea level, and gradu-



PORT LIMON, COSTA RICA.

CUT IN EARTH AT LA JUNTA ON THE COSTA RICA RAILROAD.

ally rises to elevation 45 in the Florida Lagoon, near lock No. 3. The line intercepts the drainage from about 75 square miles lying to the northward, and crosses the Guasimo, San Geronimo, Tambor Grande, San Francisco, and Danta, as well as a number of small creeks. The beds of the larger streams are from 15 to 20 feet below swamp level. The swamp bottoms are of clay silt, which may settle under the embankments, but should not offer serious difficulties to good construction. The level of the canal is to be maintained at the minimum elevation of 54.5 feet, submerging all the swamps. The flood levels appear to be about 53 feet at the Serapiqui and 56 feet in the San Francisco region, the latter being 1½ feet above the minimum stage in the canal. In order to diminish the currents through the narrow connecting channels three waste ways are provided, one in the Serapiqui Hills, 500 feet long, one of the same length in the west flank of Tamborcito, and one of 1,000 feet near the Danta. With these waste ways it is estimated that the water in the canal will never rise more than 2½ feet above the normal stage.

The waste ways are designed to be plain overflow weirs built of concrete, with the crests at elevation 54.5, the minimum canal level. At rare intervals the crest of the Danta waste way may be submerged by the San Juan floods, but the amount of water taken into the canal over it will be so small that no trouble is apprehended. The borings made at the site of the Danta waste way show unfavorable material for foundations, involving an additional expense for safe construction, for which provision has been made in the estimates. Lock No. 3, which terminates this section, is located on a rock foundation, having a lift of 18½ feet, viz., from elevation 54.5 to elevation 73 at minimum canal level. The length of this section is 16.75 miles.

SECTION FROM LOCK NO. 3 TO LOCK NO. 4.

Westward from lock No. 3 the line follows down the valley of Embankment Creek to within about 1,700 feet of its mouth, and then crosses some hills and the Machado to lock No. 4. There are two curves on the section having radii of 11,459 feet each. The excavation will be mainly in firm earth with standard slopes to correspond. Some rock will be found near the site of lock No. 4, and soft mud in crossing the valley of the Machado. The drainage area tributary to this section has not been well determined, but is taken at about 9 square miles, about 1 square mile of which will be submerged. It is proposed to control the surface of the pool, between elevations of 73 and 76 feet, by a weir 300 feet long, located in a hill a short distance east of Machado.

Two embankments will be needed between the canal and the San Juan River, one across Embankment Creek, the other across the Machado, where the crest will be about 31 feet above the bottom of the stream and about 24 feet above the swamp level. The borings show the surface material in this swamp to be soft, and some of it will have to be excavated, so that the embankment may rest on firm material. Lock No. 4 is located in a hill immediately west of the Machado. It is proposed to control the surface of the summit level of the canal between the elevations of 104 and 110 feet; hence this lock is designed to have a variable lift, the maximum being 37 feet and the minimum 31 feet. The length of this section is 2.77 miles.

SECTION FROM LOCK NO. 4 TO THE SAN JUAN RIVER.

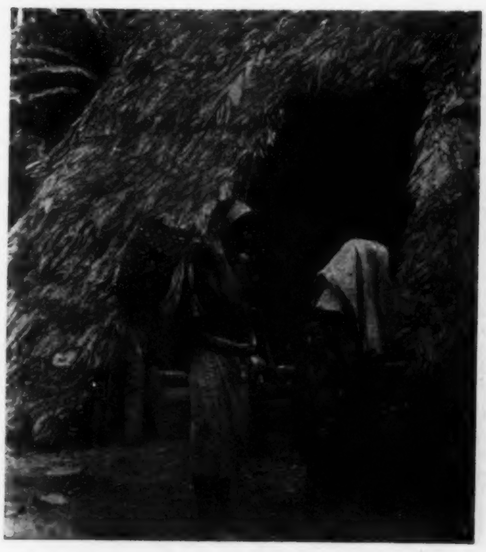
Westward of lock No. 4 the line passes through a rough, hilly region where deep cutting is encountered. About three-fourths of a mile west of the lock the depth to the bottom of the canal on the center line is 218 feet below the surface. The borings show a stratum of clay 10 feet thick, from elevation 65 to elevation 55, the top being about 4 feet below the bottom of the excavation. About 1 mile farther westward is another cut 170 feet deep on the center line, with a clay stratum 10 feet thick, the upper surface being at elevation 89. In the latter case the clay stratum is in the wetted prism of the canal. In both cases there is rock overlying the clay. It is supposed that the rock is a volcanic overflow. Where the clay shows in the wetted

SAN JORGE LANDING ON THE WEST SHORE OF LAKE NICARAGUA. OMETEPE MOUNTAIN, 5,350 FEET, IN THE DISTANCE.

BREAD FRUIT TREE.

NATIVE GROUP, WITH THATCHED HUT AND CACTUS HEDGE.

THE MILLSTONE AND POWER PLANT.



TELEMANCA MOTHER AND CHILD.

WASHING SCENE, COSTA RICA.

SCENES IN THE REGION OF THE NICARAGUA CANAL.

prism, slopes of 1 on 1 are provided for both rock and clay.

The section forms a part of the summit level, and has two curves, each of 5,730 feet radius. The point where it enters the San Juan River is 46.17 miles by the canal line from the 6-fathom curve in the Caribbean Sea. The upper end of this section is 3.3 miles by the river from the dam site at Conchuda. This dam will maintain the summit level, regulated by waste ways at the dam and in the hills a short distance southwest on the Costa Rica side. The dam, waste ways, and system of regulations are fully described elsewhere. The length of this section is 5.30 miles.

SAN JUAN RIVER SECTION.

This section embraces that portion of the river from the point where the canal enters it above the dam to Lake Nicaragua. As already stated, the San Juan River above the mouth of the San Carlos is practically free from sediment, and in this respect is well adapted for slack-water navigation. It is very crooked, however, the curves being so sharp in places that the natural channel, even if deep enough, would be difficult for large ships to navigate. Cut-offs have been located in such places, improving the course of the channel and reducing the sailing distance. These improvements leave 54 per cent of the total distance from the dam to the lake in curvature. Except in a few cases the radius exceeds 5,000 feet, but in the section between the Machuca and Castillo Rapids the limit was reduced to 4,045 feet. In the present project the curves are of larger radius than in any previous one. They could be improved, but the cost would be increased. It has been the governing motive to preserve a judicious balance between curvature and cost.

In this section there are four curves of 4,045 feet radius, one of 4,297, two of 4,911, three of 5,298, six of 5,730, two of 5,927, four of 6,876, one of 8,385, five of 11,459, and one of 17,189. The bottom of the excavated channel is established at elevation 69, giving a depth of 35 feet when the lake is at 104, its lowest stage. From the dam to the Machuca Rapids the general direction of the channel is northwesterly. The dam raises the water so as to permit a material straightening of the line on this part of the section with but little excavation. At the Patricia Rapids (in the fifty-ninth mile) the bed of the river rises above the grade of the channel bottom, and excavation is required thence to deep water in the lake.

LAKE NICARAGUA SECTION.

The line enters the lake on a curve of 11,459 feet radius, and then continues on a tangent, passing southward of the Balsillas Islands and northward of the Solentinnme group. Near the latter it crosses a submerged channel, where for a short distance no excavation will be required, and, passing around a short curve in deep water, enters a second tangent, where some excavation is required for a distance of 10.77 miles. This tangent continues to the vicinity of the mouth of Las Lajas, on the west side of the lake. The lake bottom on the sailing line lies below the grade of the canal bottom for a distance of 41.78 miles; the remainder, 28.73 miles, will require excavation. On approaching the mouth of Las Lajas, the line swings to the westward in deep water to the long tangent at the east end of the western division of the canal. The bottom from Fort San Carlos to deep water in the lake consists of soft mud 6 to 17 feet deep, underlaid by hard clay and sand. The mud is so soft in places that it is difficult to determine its surface. The steamboat navigating the lake pushes it way through several feet of it when the lake is low. This material will take a flat slope, and after a channel is excavated through it there will be some expense for maintenance.

On the west side the excavation in the lake commences 1.52 miles from the shore. It will consist chiefly of rock, and, as it is submerged, is estimated at the price for rock excavation under water. The material excavated from the west side of the lake can be wasted where it will form jetties for the protection of this entrance. The bottom width of the channel in excavation in the lake, both on the east and west sides, will be 300 feet.

The total length of the lake division is 70.51 miles.

LAKE NICARAGUA TO LOCK NO. 5.

The entrance to the canal from Lake Nicaragua is about 1,100 feet north of the mouth of the Rio Las Lajas. The line extends in a southwesterly direction, following first Las Lajas, which it crosses four times in a distance of 1½ miles, then following the general course of a small tributary, called the Guiscoyol, to the continental divide. The surface of the ground from the lake rises gradually until the divide is reached at elevation 153, a distance of about 5 miles from the lake shore. The highest point on this section is a small projecting hill three-fourths of a mile east of the divide, at elevation 156 on the center line.

From the divide the line follows the valley of the Espinal to the Rio Grande, and then continues in the valley of the latter to the Pacific. From the mouth of the Espinal to lock No. 5 the valley of the Rio Grande is narrow and crooked, with hills on either side rising to elevations of 150 feet and upward. Here the line passes through several spurs, with rather deep but short cuts. The most important feature of this section is the cut through the west divide. Its maximum depth on the center line of the canal is 87 feet; for a distance of about 3 miles the average cut is about 75 feet. The rock is of all degrees of hardness from partially disintegrated sandstone to hard trap. Lock No. 5 is located in a hill on the north side of the Rio Grande at Buen Retiro, and will have an excellent rock foundation. On the south side of the lock a small dam will be required across the river to the adjacent hills to maintain the summit level. This dam is designed to be of earth with a masonry core wall extending to rock. The lock will have a variable lift from 22½ to 28½ feet, depending on the height of the lake. The section contains four curves with radii of 17,189, 5,730, 5,209, and 5,056 feet, respectively. Three of these are between the divide and the lock. The length of this se^tion is 9.09 miles.

LOCK NO. 5 TO LOCK NO. 6.

The valley or gorge of the Rio Grande gradually widens in this section, opening into the so-called Tola Basin. The soil of the Rio Grande Valley is a light, sandy loam, readily acted upon by currents. The grade of the canal is established so low that the prism will be almost wholly in excavation, and the embankments will not be heavy and can easily be protected. This section contains a single curve of 4,982 feet radius. A by-pass in lock No. 5 will provide water for this level. A small waste way will discharge surplus waters into the Rio Grande. The excavation will consist mainly of sandstone much disintegrated near the surface, but less so farther down.

Lock No. 6 is located in a small hill on the south side of the Rio Grande about one-half mile above the mouth of the Rio Tola. The foundation is on rock. The lift is 28½ feet. The length of this section is 2.04 miles.

LOCK NO. 6 TO LOCK NO. 7.

In this section the line crosses the bed of the Rio Grande several times, and short embankments 20 to 30 feet in height will be required; elsewhere the embankments will be unimportant, the grade line being low, as in the preceding section. This section contains a single short curve of 5,056 feet radius. The excavation will be mostly in sandy earth, except in the vicinity of the lock sites. While the excavation is sandy, it contains enough earthy material to form water-tight embankments. A new channel will have to be provided for the Rio Grande for nearly the entire distance. This will receive the drainage from the north side of the valley, including that of the Tola. On the south side the drainage will be received into the abandoned bed of the Rio Grande, and thence discharged into the canal. A waste way located near the upper end of the section will discharge surplus water from the canal into the new channel of the river.

Lock No. 7 is located in a hill at the site formerly proposed for the south abutment of La Flor dam. The lift will be 28½ feet. The prism of the canal will be mostly in sandy silt with side slopes of 1 on 3. The length of this section is 1.83 miles.

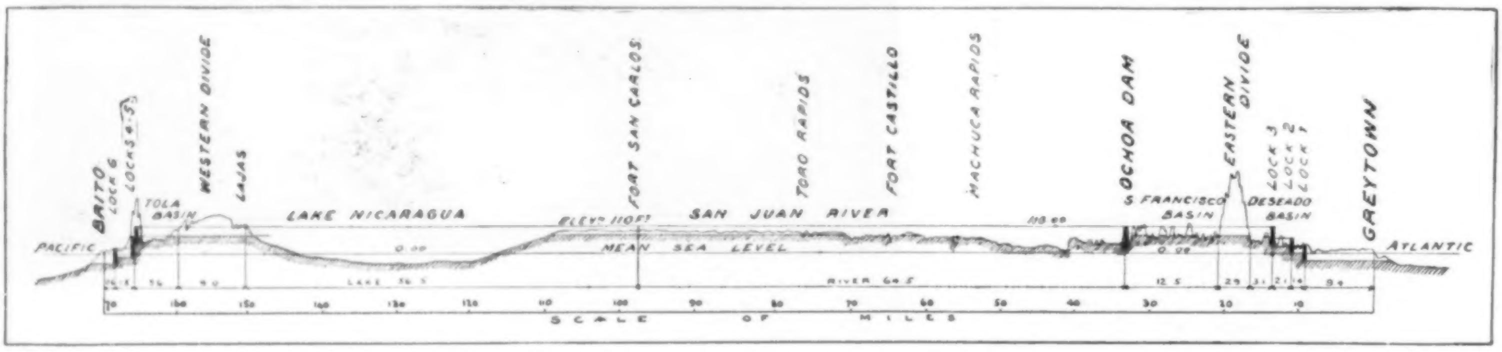
LOCK NO. 7 TO LOCK NO. 8.

The conditions in this section are almost exactly the same as in the preceding one. The material consists chiefly of light sand mixed with loam, which can be dredged by machines taken through lock No. 8 after the latter is built. It contains two short curves of 5,730 feet radius. A small waste way is located near the upper end of the section where the canal is entirely in excavation. It will not have a rock foundation, and will be merely a depressed section of canal bank with protected surface.

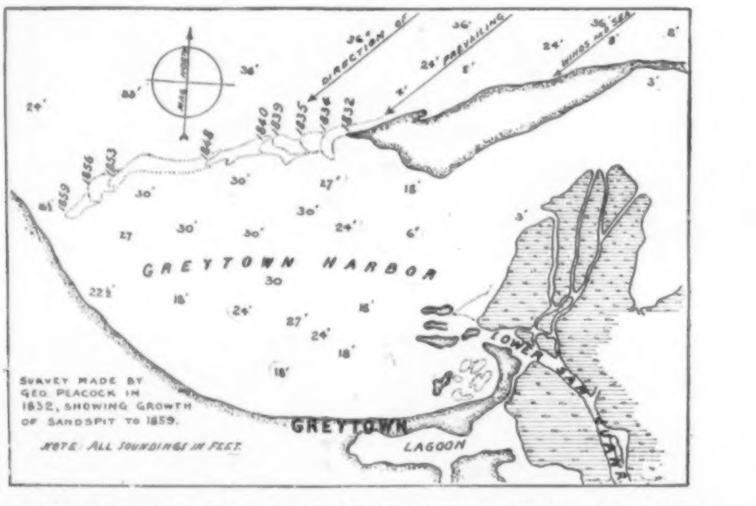
Lock No. 8, which connects with tide water, is located in a projecting spur, and will have a rock foundation. Its lift will vary with the tide from 28½ feet at mean low water to 20½ feet at mean high water. The length of this section is 2.43 miles.

LOCK NO. 8 TO THE PACIFIC.

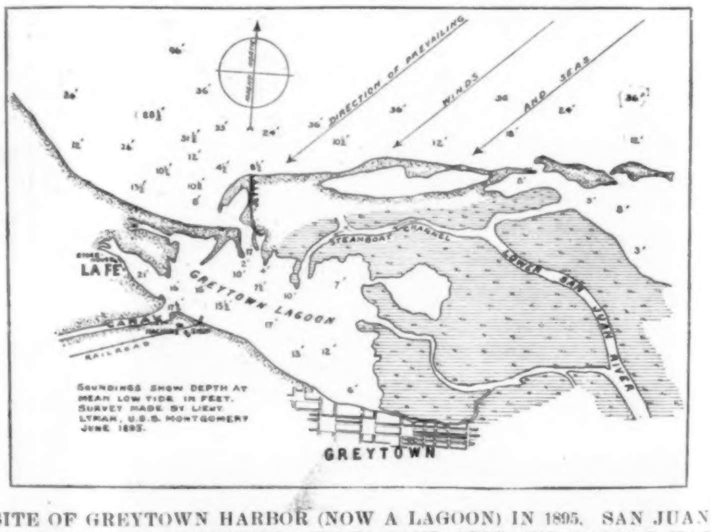
This includes a short section of the canal proper and an artificial harbor at Brito. The excavation in this section consists mostly of sand. Some rock will be encountered near the lock site. The entrance to the harbor will be straight and have a width of 500 feet on the bottom. The length of this section to the 6-fathom curve in the Pacific is 1.15 miles. The prism, except near the lock, will have side slopes of 1 on 3. The total distance from Lake Nicaragua to the 6-fathom curve in the Pacific is 17.34 miles.



PROFILE OF THE NICARAGUA CANAL AS PROPOSED BY THE MARITIME CANAL COMPANY, 1893.



GREYTOWN HARBOR IN 1832, SHOWING GROWTH OF SAND SPIT TO THE WESTWARD UNDER ACTION OF PREVAILING TRADE WINDS.



SITE OF GREYTOWN HARBOR (NOW A LAGOON) IN 1895. SAN JUAN DELTA HAS EXTENDED OUT TO SAND SPIT AND HARBOR HAS SHOALED TO 16 FEET.

HARBORS.—LACK OF HARBOR FACILITIES.

As there is no natural harbor at either end of the proposed canal artificial harbors will have to be constructed. This lack of harbor facilities will be seriously felt on the east side in the early stages of the work, as the difficulties and expense of landing material before the harbor can be constructed are great.

GREY TOWN HARBOR.

A fine harbor once existed at Grey Town, with about 20 feet of water at the anchorage and in the entrance. This was not such as is often found at the outlet of a large river like the San Juan, where the current scours an entrance, but rather a bight or protected area formed on the lee side of a sand spit which was itself built by the action of the waves and sea currents acting under conditions which favored such formation. A study of the various maps of Grey Town from the earliest to the latest reveals, it is believed, the processes by which natural forces acting on the movable sands composing the delta of the San Juan River have formed successively in ages past harbors which were afterward converted into lagoons or lakes. The process seems still to be going on, and Grey Town lagoon is the latest development. Ibo, Barco, Sucio, and Shepherds lagoons were probably formed in the same way and by the same agencies.

The harbor which this Commission proposes at Grey Town will have a length of 2,500 feet and a width of 500 feet, widened at the inner end to 800 feet in order to provide a turning basin. The depth throughout the harbor and entrance will be 35 feet. The entrance will be located about one mile east of the old jetty of the Maritime Canal Company.

BRITO HARBOR.

The Rio Grande empties into the Pacific Ocean at Brito, close under the rocky headland of that name. At low water in the dry season there is about 3 feet depth at the entrance, but as the tide rises and falls from 8 to 10 feet the depth is much increased at the high stage.

REGULATION OF LEVEL OF LAKE NICARAGUA.

The summit level of the canal is the surface of the water in the lake. A dam across the San Juan River at Conchuda, 52.9 miles from the lake, extends the summit level to that point. In other words, if a dam be built at the Conchuda site an arm of the lake will reach to it, carrying the lake level during a period of no discharge to the same point. The canal will leave this arm of the lake at a point 3.3 miles up stream from the dam. These are general conditions which must be preserved, and the problem of the regulation of the lake level involves the control of the latter within such limits, more or less exact, as will never permit the navigable depth of the summit level to be anywhere less than 35 feet on the one hand, nor permit the lake to rise materially beyond a determinate elevation on the other. This regulation can be accomplished by the construction of dams across the Rio Grande west of the lake and across the San Juan on the east side, both being designed with suitable waste ways for the discharge of surplus water, or all the surplus water may be wasted through the San Juan. As wasteweirs at or near the Conchuda dam may be given sufficient capacity to discharge all the wastage, and as the latter may readily be discharged through the lower San Juan, the entire regulation works are designed to be located at or in the immediate vicinity of the Conchuda dam.

CONCHUDA DAM.

The most important structure on the route is the Conchuda dam. Before deciding on its location a large number of borings were made to ascertain the depth to suitable hard rock for the foundation, both at the Conchuda site, and at the one near Boca San Carlos suggested by the Nicaragua Canal Commission. At the latter site the greatest depth to hard rock is 120 feet below the surface of the river at low stage. At the Conchuda site the greatest depth to hard rock is 82 feet, which is very important, because the foundations will probably have to be placed by the compressed-air process, and the depth is well within that at which the foundations of many bridge piers have been built by the same method.

The portion of the dam across the river and the swamp on the Costa Rica side, for a total distance of 731 feet, will consist, below low water, of caissons placed close together with the joints between them sealed. Upon the platform thus made the part above low water will be built as a continuous monolithic structure and will support the sluices already mentioned. From each end of this portion the dam will be built for a further distance of 100 feet into the hillsides in open excavations and with cross section designed to sustain the full head of water. Core walls extend 100 feet farther on the Costa Rica side and 240 feet on the Nicaragua side. The total length of the dam, including core walls, will be 1,271 feet. The foundation is on hard rock for the entire length.

In its preliminary report this Commission estimated the time for completing the entire work on the Nicaragua route at about ten years. This was based on the expectation that two years would be required for preparatory work and eight years to construct the dam at Boca San Carlos, which would be begun only after a temporary harbor at Grey Town was constructed and other work done. A more favorable site for the dam having been found at Conchuda, its construction is no longer the controlling feature. It is estimated that this dam can be built in four years.

RAILROAD.

A railroad for construction purposes will be necessary, and provision has been made for building one from Grey Town to the mouth of the Sabalos River, and from the west shore of the lake to Brito. The intervening space can be traversed by boats, the river between Fort San Carlos and the Sabalos being deep enough to accommodate, without improvement, such vessels as can reach the deep water of the lake from the San Juan. It is possible that the portion of the railroad between the Conchuda dam and Sabalos might be dispensed with, as the work between those points is almost entirely in the river, but it was thought best to provide convenient communication between the two oceans, as a transfer of material and men from the east to the west side of the lake, or from the west to the east side, might become important. The portion of the river between the dam and Sabalos is navigable only for small steamers.

The railroad has been located on the south side of the canal, with the grade not exceeding 0.5 per cent. It is to be of standard gage, supplied with sidings, stations, and water tanks, and fully equipped with the necessary rolling stock. The estimate is made on the basis of $75,000 per mile for the railroad completed and ready for operation.

Summing up the various items, the total estimated cost of constructing the Nicaragua Canal is as follows:

Total estimated cost.	Miles.	Cost.
Grey Town Harbor and entrance	2.15	$2,198,800
Section from Grey Town Harbor to lock No. 1, including approach wall to lock	7.44	4,899,887
Diversion of lower San Juan		40,100
Diversion of San Juanillo		116,760
Lock No. 1, including excavation	.20	5,719,686
Section from lock No. 1 to lock No. 2, including approach walls, embankments and wasteway	10.96	6,296,632
Lock No. 2, including excavation	.20	4,050,270
Section from lock No. 2 to lock No. 3, including approach walls, embankments, and waste ways	16.75	19,390,654
Lock No. 3, including excavation	.20	3,832,745
Section from lock No. 3 to lock No. 4, including approach walls, embankments, and wasteway	2.77	4,310,580
Lock No. 4, including excavation	.20	5,655,871
Section from lock No. 4 to San Juan River, including approach wall and embankments	5.30	8,579,431
Conchuda dam, including sluices and machinery		4,017,650
Auxiliary wasteway, including sluices, machinery, and approach channels		2,045,322
San Juan River section	46.17	23,155,670
Lake Nicaragua section	70.51	7,877,611
Lake Nicaragua to lock 5, including approach wall to lock and receiving basins for the Rio Grande and Chocolata	9.09	19,566,575
Diversion of Las Lajas		199,382
Lock No. 5, including excavation	.20	4,913,512
Dam near Buen Retiro		125,591
Section from lock No. 5 to lock No. 6, including approach walls and wasteway	2.04	3,259,283
Lock No. 6, including excavation	.20	4,368,667
Section from lock No. 6 to lock No. 7, including approach walls, embankments, and wasteway	1.83	2,309,710
Diversion of Rio Grande		176,180
Lock No. 7, including excavation	.20	4,709,502
Section from lock No. 7 to lock No. 8, including approach walls, embankments, and wasteway	2.43	1,787,496
Diversion of Rio Grande		117,580
Lock No. 8, including excavation	.20	4,920,899
Section from lock No. 8 to Brito Harbor, including approach wall	.23	553,476
Brito Harbor and entrance, including jetty	.92	1,509,470
Railroad, including branch line to Conchuda dam site, at $75,000 per mile	17.34	7,575,000
Total	186.66	$158,220,052
Engineering, police, sanitation, and general contingencies, 20 per cent		31,644,010
Aggregate		$189,864,062

TRADE NOTES AND RECEIPTS.

White Coating for Leather.--

White glue	1000
Gum arabic	600
Water	6400

Soak for a day, heat to a boil and add:

Vinegar	200
Precipitated chalk	1800

The mixture is stirred until cool and should be diluted with sufficient water that it can be conveniently applied like paint.—Neueste Erfindungen und Erfahrungen.

Lemonade Powders and Lemonade Drops.—As the fundamental substance, prepare a mixture of powdered citric acid 45 grammes and sugar 950 grammes, and aromatize with lemon oil 3 to 4 drops, raspberry ether 10 drops, woodruff essence 15 drops and orange oil 3 drops. If a lemonade powder prepared according to the above recipe is mixed with sodium bicarbonate and tartaric acid in the proportion of lemonade powder 19, sodium bicarbonate 19, and tartaric acid 9, a mixture is obtained which can be sold in powder form, as well as in a compressed form as lemonade drops.—Chemiker Zeitung.

New Cleansing Agent for Fermentation Plants.—A new cleansing agent for apparatus of the fermentation industry, especially for the removal of rests of malt, mash, wort, beer and yeast from pipes, fermentation vats, etc., has been patented in Austria.

The same consists of a mixture of alkaline hypochlorite and alkaline hydrate, and is produced in the simplest manner by mixing a chloride of lime solution with soda, which separates the sodium hypochlorite in solution from the lime carbonate precipitated out, and adding caustic soda.

This mixture, according to the claims of the inventor, is an excellent mucus-dissolving liquid, which dissolves the tough mucus resulting from organisms—growths of yeast, fungi and bacteria—in the little accessible conduits more readily than any other medium.

Tests are said to have demonstrated that all organisms are immediately destroyed by the strongly oxidizing action of the hypochlorite. Hence, in using this preparation not only the outer layer of the deposited mucus substances are sterilized, but the medium penetrates their interior by dissolving the mucus.—Technische Berichte.

The Formation of Varnish Not an Oxidation Process.—Highly important statements were made at the last meeting of German naturalists and physicians in Hamburg by Dr. Kronstein, in the department of applied chemistry. After the speaker had explained the nature of polymerization by the finding of an intermediary product which always consists of 12 molecules, he pointed out that the formation of varnish is not an oxidation process, as has been assumed heretofore, but a polymerization process. He arrives at the same conclusion regarding linoxin, which is of eminent importance in the linoleum industry and represents the highest stage of the polymerization of linseed oil.

In the latter part of his lecture he spoke exhaustively on resins. He succeeded for the first time in carrying out the synthetic formation of the resins, which in regard to their physical as well as their chemical nature were found to be perfectly identical with the gums occurring in nature. Thus he exhibited a resin produced by the new process which in every way resembles natural amber, in color as well as hardness.

In conclusion he spun out a new resin formation theory relative to hard gums as well as to soft gums and balsams.—Farben Zeitung.

TRADE SUGGESTIONS FROM UNITED STATES CONSULS.

Artificial Fuel in Belgium.—The principal, and, in fact, practically the only, artificial fuel manufactured in Belgium consists of a composition of coal dust made in the form of large bricks, either solid or perforated, and used chiefly as fuel for steam engines, locomotives, etc. Small bricks are also manufactured in the form of cubes or of parallelograms, in round or oval balls, and are used in place of anthracite coal for stoves built on the American system.

The material employed for the manufacture of these bricks is coal dust, which has generally been previously washed. The glutinous element used in the composition is the residue from the distillation of coal tar, which residue is produced in large quantities by the manufactories for the distillation of tar obtained from the gas and coke plants. The bricks thus manufactured contain 94 per cent of coal. The coal dust is usually obtained from what is called hard coal in this country (not anthracite) and from coal which is said to be one-fourth soft.

In 1900, 1,395,910 tons of large and small bricks and balls were manufactured. In this amount is not included the production of some minor manufactories where small balls without tar residue are made from coal one-half soft.

The material used in these small balls is held together by injecting steam into the mass while it is being molded and pressed. About 1,000 tons of these small balls, without tar residue, were manufactured in 1900.

The average price at the manufactory of the large bricks and balls made with tar residue was, in 1900, 23.56 francs ($4.55) per ton.

This price in 1899 was 16.05 francs ($3.10); in 1898, 19.30 francs ($3.72); in 1897, 12.51 francs ($2.41); in 1896, 11.96 francs ($2.31); in 1893, 11.29 francs ($2.18)—at which date it reached its lowest limit.

The commercial movement in these composition bricks of coal is rather important in Belgium, and is increasing every year. In 1900 the exportation amounted to 604,864 tons, as compared with 525,625 tons in 1899.

Composition bricks of coal are manufactured at the following places:

Chatelet, by Société des Charbonnages d'Ormont.

Charleroi, by D. Evard and Scripel & Bellière.

Châtelmeau, by Société des Agglomeres de Houille.

Marcinelle, by Société des Agglomeres de Houille Reunis du Bassin de Charleroi.

Mariemont, by Société Anonyme des Charbonnages de Mariemont.

Manage, by Société Anonyme des Charbonnages de Bray, Maurage et Baussoit.

Monceau St. Sambre, by Société Anonyme des Charbonnages de Foste-Taille.

Montigny St. Sambre, by Société Anonyme des Charbonnages Réunis de Bonne-Espérance.

Paturages, by Société Anonyme des Charbonnages de Paturages et Wasmes.

Roux, by Société Anonyme des Agglom[illegible]és de Roux.

Tilleur, by Société Anonyme des Charbonnages du Horloz.

Micheroux, by Société des Charbonnages du Hasard.

Flémalle-Grande, by Société Anonyme des Charbonnages de Marihaye.

Jumet, by Société Anonyme des Charbonnages d'Amercoeur.

Marchienne au Pont, by Dehaynin & Co.

Ressaix, by Société Anonyme des Charbonnages de Ressaix, Leval, Peronne & Ste. Aldegonde.

Marcinelle, by Fabrique d'Agglomérée de Houille L. Watin.

Bernissart, by Le Charbonnage de Bernissart.

PEAT AND WOOD.

There exist in the northwest and also in the southeast of Belgium some small plants for the manufacture of fuel from peat. As the peat in Belgium is of rather an ordinary quality, containing a great deal of earth, sand, and other mineral products, it is used for fuel purposes only in the district where it is produced. There is no exportation of this product.

There is a small amount of artificial kindling produced, which is made from sawdust and small bits of wood held together by a glutinous substance produced from the tar of wood. This kindling is pressed into the form of bricks, which are grooved for the purpose of readily dividing them into four parts.

CHARCOAL.

Charcoal is produced in Belgium, sometimes from the distillation of wood, but usually by the slow combustion of wood in charcoal kilns. The product is principally used in the refining of metals.—Lawrence Townsend, Minister at Brussels.

New Gelatin Factory in France.—A new gelatin factory has just commenced manufacturing near the port of La Pallice. This may be of interest to Americans, as it is expected that a large proportion of the product of the factory will be sold in the United States. It is owned and operated by a firm known as Jules Bertrand & Co., and its equipment is as nearly perfect as modern science can make it. The motive power in each of the several buildings is electricity, supplied from a centrally located generator to motors distributed throughout the premises. Part of the machinery—including several special pumps—is of American manufacture. The production will consist of fine glues and gelatins, the latter including the very best bleached white gelatin. The bones used have up to the present time been received from India, as it is claimed that they produce better qualities of certain kinds of gelatin. The question of importing American crushed bone would receive serious attention on the part of the manager, Mr. Bertrand. The price per ton delivered at La Rochelle should be stated. It should be remembered that bone dust or bone meal is not desirable for the supplies of this factory, what is known as crushed bone only being used. Bone meal, when subjected to

acids in the vat, becomes a mass too solid to be readily worked, and great difficulty has been found in cleaning and bleaching the animal matter which results from the bones being subjected to chemicals.

The system is what is known as the modern acid process. The acids are produced in a neighboring factory. The capacity of the gelatin works is 1,200 tons per year; the actual amount produced being a little less than half of that. One of the most striking features of the establishment is the cleanliness seen everywhere, and the absence of unpleasant odors, such as are usually found in institutions of this kind.—George H. Jackson, Consul at La Rochelle.

Industrial Depression in Austria-Hungary.—There is every indication that Austria-Hungary is on the eve of great industrial depression. The wave of inactivity which has been influencing Germany for the past two years appears to be moving eastward. Until recently, iron, steel, electricity, petroleum, and nearly all other great industries seemed to be in a flourishing condition, the only apparent exception being the textile branch. Here, the crisis came more than a year ago. A short period of unusual prosperity had caused a rapid increase in the number of spindles and looms. This was followed by overproduction, and in time by stagnation. The crisis was doubtless hastened by the extraordinary rise and subsequent sudden fall in the price of raw materials and a consequent demoralization in the market. While the cotton and woolen mills have gradually reduced their stocks and most of them have resumed work—though prices are still far from being profitable—other more important industries are beginning to feel the paralyzing effect of overproduction and ruinous foreign competition.

About a year ago,* I reported that at the request of the native petroleum refiners, the government had increased the duty on crude petroleum from 2 to 3½ florins gold (96.5 cents to $1.69) per quintal. As it was intended, this measure entirely stopped Russian imports and gave a great impetus to the home refining business. Several new plants were established, and in many instances the capacity of those already in existence was increased. Overproduction followed, prices fell, and the business in Austria-Hungary has suffered seriously.

In many of the iron and steel works in northern Austria, work has been reduced, and some establishments have even notified their men that if orders are not soon received they will shut down at the close of the year. It is furthermore stated that the Austrian locomotive works have not received a foreign order for months, and that, inasmuch as with their present force of employés the entire home demand for 1902 will be supplied within a few months, the prospects for the ensuing year are rather gloomy. Car shops, furniture and tool factories, sawmills, and similar establishments are only partially employed, and the building trades complain of general inactivity.

That the condition is critical is universally admitted. The situation has been the subject of earnest discussion in the Austrian and Hungarian parliaments, as well as in the various chambers of commerce and in the municipal councils of the leading cities of the monarchy. Meetings of representatives of the principal industries affected by the present crisis have also been held, for the double purpose of surveying the field and of devising, if possible, measures of relief. The governments of both halves of the monarchy have been petitioned to come to the rescue of the languishing industries, by entering as soon as possible upon the execution of certain public works originally planned for 1902 and 1903, and by letting at once the contracts for such army supplies and railway rolling stock as will be needed during the coming year. Both governments have declared themselves disposed to favor the proposed measures, and a number of large contracts will doubtless be let at once, and others will follow as soon as the necessary appropriations have been made by the respective parliaments. It has been officially stated in the Austrian parliament that the Ministry of Railroads will expend in the near future, for the purchase of locomotives, cars, track material, etc., about 57,000,000 crowns ($11,570,000), and that, if the budget for 1902 is promptly passed, other contracts, amounting to 30,000,000 crowns ($6,090,000), will soon be let by the several departments of the government.—Frederick W. Hossfeld, Consul at Trieste.

Coal in Spitzbergen.—Consul-General Bordewich writes from Christiania, November 9, 1901, in regard to coal deposits recently found in Spitzbergen. According to newspaper reports, there are indications that remunerative coal mining might be conducted in the islands, provided sufficient capital were invested. It is stated that the shaft sunk by the people of Trondhjem is located near the shore, at Advent Bay, where a safe harbor is found. After having blasted 40 feet through clear ice, solid rock was struck, and at a depth of 60 feet dry coal of good quality was found. The layer of coal had a thickness of 10 feet and appeared to be extensive. In the mountain were also found petrified apples, pears, nuts, and even leaves of bananas.

It is understood, adds the consul-general, that coal is being mined in the Faroe Islands under Danish management.

* Consular Reports No. 246; Advance Sheets No. 924.

INDEX TO ADVANCE SHEETS OF CONSULAR REPORTS.

No. 1226. December 30.—Coal in France—American Coal in Germany—New Cable between Ireland and the Azores.

No. 1227. December 31.—New Railroads in Russia—Stock Companies in Russia—*Consular Plan in Export Trade—*Opening for American Overalls in England—*Gold in Madagascar—*German Meat Inspection.

No. 1228. January 2.—American Coal in Germany—Cotton-Oil Exports from Marseilles to the United States—Payment of Customs Duties in Gold in Spain—Walnut Prices in Marseilles.

No. 1229. January 3.—Coffee Market of Brazil—The Flour Market at Rio de Janeiro—Port Charges at Copenhagen—World's Shipbuilding for 1900.

No. 1230. January 4.—Trade Opening in Malta—*Exhibition and Congress of Fisheries at St. Petersburg—Fresh-Meat Exports from Uruguay—Wheat Crop in Uruguay—Shipping in Liberia.

The Reports marked with an asterisk (*) will be published in the SCIENTIFIC AMERICAN SUPPLEMENT. Interested parties can obtain the other Reports by application to Bureau of Foreign Commerce, Department of State, Washington, D. C., and we suggest immediate application before the supply is exhausted.

THE

Scientific American Supplement.

PUBLISHED WEEKLY.

Terms of Subscription, $5 a Year.

Sent by mail, postage prepaid, to subscribers in any part of the United States or Canada. Six dollars a year, sent, prepaid, to any foreign country.

All the back numbers of THE SUPPLEMENT, from the commencement, January 1, 1876, can be had. Price, 10 cents each.

All the back volumes of THE SUPPLEMENT can likewise be supplied. Two volumes are issued yearly. Price of each volume, $2.50 stitched in paper, or $3.50 bound in stiff covers.

COMBINED RATES.—One copy of SCIENTIFIC AMERICAN and one copy of SCIENTIFIC AMERICAN SUPPLEMENT, one year, postpaid, $7.00.

A liberal discount to booksellers, news agents and canvassers.

MUNN & CO., Publishers, 361 Broadway, New York.

TABLE OF CONTENTS.